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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1037

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER August 19, 1922

THE CONTROL OF SAP-STAIN, MOLD, AND INCIPIENT DECAY IN GREEN WOOD WITH SPECIAL REFERENCE TO VEHICLE STOCK

By

NATHANIEL O. HOWARD, Pathologist
Office of Investigations in Forest Pathology

(In cooperation with the Forest Products Laboratory of the United States Forest Service, Madison, Wis.)

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INTRODUCTION.

During periods of transit and storage, previous to its ultimate manufacture, green timber containing a high percentage of sapwood often suffers considerable damage. This is particularly true during the late spring and summer months when deterioration brought about mainly through a discoloration of the sapwood, known as sap-stain, sometimes necessitates degrading on a large scale. This staining of timber has occasioned severe losses in Europe as well as in the United States, and many expensive investigations have been made to determine the nature of the stain and to discover a satisfactory remedy.

[1] The writer wishes to acknowledge his indebtedness to Mr. C. J. Humphrey, in charge of the Laboratory of Forest Pathology, Bureau of Plant Industry, in cooperation with the Forest Products Laboratory, Madison, Wis., for facilities and for advice in outlining the work; to Dr. Charles Thom and Miss Margaret B. Church, of the Bureau of Chemistry, for the identification of mold fungi; to Mr. H. D. Tiemann, physicist and specialist in kiln drying, Forest Products Laboratory, Madison, Wis., for the loan of photographs; to Mr. Joseph Ashcroft, of Poplar Bluff, Mo., for cooperation in the experimental dipping of spokes; and to all others who, by information, suggestion, or criticism, have contributed to the preparation of the manuscript of this bulletin.

The molding of green timber has frequently been confused with sap-stain as well as with incipient decay. However, in so far as the production of permanent stain or the effect upon the durability of the wood is concerned, molding is of comparatively little importance. Incipient decay caused by true wood-destroying fungi, on the other hand, is of great importance.

Early in the year 1918 the attention of the Office of Investigations in Forest Pathology was called to staining and molding occurring in green raw material by the wood-stock committee representing the National Implement and Vehicle Association and other vehicle and vehicle parts manufacturers through the Forest Products Laboratory of the United States Forest Service, Madison, Wis. The present investigation arose in connection with raw hardwood stock used in the manufacture of escort wagons and artillery carriages. A large quantity of this material was at that time being sawed or turned, largely from green instead of seasoned stock and shipped green from the saw. In some cases it was found necessary to cull severely such stock at destination, owing to the presence of mold, stain, or incipient decay which had developed during transit and while in storage. In cooperation with the Forest Products Laboratory and the wood-stock committee, a questionnaire [2] was sent to a number of the contractors for Army vehicles and parts and to producers of wood stock. Personal investigations were also made of the conditions existing at 45 mills and factories engaged in the sawing of timber, dimension stock, and veneer, or in the manufacture of airplanes, furniture, flooring, handles, vehicles, and vehicle parts. Most of these mills were located in the central and southern portions of the United States and were directly concerned in the production of war material. The object of both questionnaire and personal investigations was to gain information concerning the general sanitary conditions existing in the woods, railway cars, sheds, warehouses, and kilns; the details of manufacture of many vehicle parts; the extent of deterioration occurring in green raw material; the financial losses occasioned thereby; and, particularly, any practical methods of handling green wood stock that would prevent the development of stain and mold therein.

The investigations showed that many of the firms had experienced considerable pecuniary losses, which were due to the necessity of using a high percentage of green stock; to a shortage of cars, resulting in the congestion of material in the woods and railroad

[2] National Implement and Vehicle Association and other Vehicle and Vehicle Parts Manufacturers. Information Division of the Wagon and Vehicle Committee and the Wheel Manufacturers' War Service Committee. Wood Stock Committee. Sap-stain and mold in green lumber. Nat. Implement and Vehicle Assoc., etc., Bul. 24, 2 p., 1 fig. 1918. A. B. Thielens, chairman. Multigraphed.

yards; to lack of time for the proper air seasoning or kiln drying preparatory to shipment; and, finally, in some cases to a failure to understand the conditions necessary to safeguard the stock while in storage or in transit. Many of these losses due to emergency will be considerably reduced upon return to normal conditions.

Some manufacturers consider it important that, in order to overcome losses due to checking, certain kinds of stock produced at many of the smaller mills be shipped to them in a green rather than in a partly seasoned condition. They claim that these mills, not being equipped for the proper drying of stock preliminary to shipment, make it necessary for the manufacturer to insist that material from such sources be shipped in a green condition to the factory, where suitable means for storage and drying are maintained. Close attention must be paid to the handling of this material in transit or in storage if deterioration due to fungi is to be prevented.

The necessity for a careful conservation of timber in the United State is becoming more and more apparent (*53*,[3] *54*[4]). Measures, then, that will assist in preventing or reducing losses due to fungous attacks are of importance.

This bulletin presents a brief review of our knowledge of sap-stain and mold, a consideration of the causal organisms responsible for such deterioration in green wood stock, the results of the new investigations, and finally a summary of some of the important methods of control.

SAP-STAIN.

The "bluing," or sap-stain, of pine timber has been observed in Europe for many years. Both Hartig (*17*, *18*) and Frank (*11*) refer to it in their investigations of plant diseases. Rudeloff (*36*) studied the effect of blue stain on the strength of pine wood. Münch (*31*) not only examined the properties of blued coniferous wood but also investigated the causal organisms and determined the optimum conditions for their development in the wood. In the United States considerable attention has been given to the subject by such investigators as Von Schrenk (*41*, *42*, *43*), Hedgcock (*19*, *20*), Rumbold (*37*, *38*), Weiss and Barnum (*56*, *57*), and Bailey (*5*). Many of the investigations have been made in connection with the sap-stain of hardwoods as well as conifers.

[3] The serial numbers (*italic*) in parentheses refer to "Literature cited" at the end of this bulletin.

[4] These two reports on Senate Resolution No. 311 by the Forest Service of the United States Department of Agriculture may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 25 cents and 5 cents, respectively, per copy.

DEFINITION OF SAP-STAIN.

The term "sap-stain" refers to the blue, green, brown, or red discoloration which often may be observed in the sapwood of timber derived from several kinds of broad-leaved and coniferous trees. It must not be confused, however, with the superficial discolorations produced mechanically, i. e., by collections of dirt and coal dust, by deposits from the drip in leaky cars and sheds, or from the condensed moisture in kilns. Such deposits may occur upon heartwood as well as sapwood. Neither should it be confused with the common blue-purple stain apparent when rusty saws are used on certain green wood, such as oak. This stain results from the reaction between the tannic acids of the wood and the iron compounds from the saw. Finally, it must not be confounded with the variously colored superficial growths of molds or the more or less deep seated sap-rot, with its brown to bleached appearance and its tendency to produce a punky consistency of the sapwood itself.

There are two quite generally recognized classes of sap-stain: (1) The chemical stain, said to be produced by chemical reactions brought about through the agency of certain oxidizing enzyms present in the wood itself; and (2) fungous stains known to be caused by several species of fungi.

CHEMICAL STAINS.

Chemical stains due to enzyms cause discolorations in both the sapwood and the heartwood of sugar pine and hard maple (Tiemann, *51*, p. 185; also Pratt, *34*, p. 305–307). Such stains develop during air drying, particularly under warm and humid conditions, or in the kiln, and give more or less permanent discolorations to the wood, to wit, a brown stain in sugar pine (fig. 1) and a cherry color in hard maple. These defects cause degrading (*34*) and often result in financial losses. According to Bailey (*5*), when freshly cut sapwood of alder, birch, cherry, or red gum is exposed to the air during extremely warm and humid weather, chemical reactions often take place and within a few hours produce colored substances in the wood. Bailey (*5*) states that the microscopic examination of sections of such wood indicates that the colored substance develops particularly within the pith rays and the parenchyma cells. He states that certain soluble enzyms which assist in the oxidation of organic compounds and are of prime importance in the nutrition and growth of living organisms are widely distributed in plants and animals and may also produce post-mortem discolorations of certain organic compounds (see also Clark *8*, *9*). Yoshida (*59*) discovered in 1883 that an oxidizing ferment is responsible for the oxidation of the latex in certain species of Rhus and the formation thereby of black varnish, or lacquer. Investigations have also shown that discolorations in fruit juices,

vegetables, cereals, mushrooms, and various soft plant tissues are brought about through the agency of certain oxidizing ferments, the oxidases and the peroxidases (Asō *1*, *2*, *3*; Clark, *8*, *9*; Kastle, *27*). These ferments are sometimes distinguished by the production of a strong blue color in a tincture of guaiacum when used in the presence of oxygen or hydrogen peroxid (Haas and Hill, *16*, p. 383). Bailey (*5*) states that the activity of these oxidizing enzyms increases with the rise in temperature to a certain point, which may be called the optimum, and then decreases as the temperature is raised above this point. In almost every case, according to the same authority, the activity is entirely destroyed before a temperature of 100° C. (212° F.) is reached. He also states that the activity of these oxidizing ferments is diminished or destroyed by certain antiseptics and by other chemical substances. According to Asō (*1*, *2*), such substances as tannin, sodium fluorid, and sodium silicofluorid, interfere with the color reactions normally produced by oxidases. Bailey (*5*) notes the strong similarity existing between the oxidizing activities of these enzyms and the chemical reactions responsible for certain kinds of sap-stain, namely, post-mortem oxidation with change of color produced by solutions in contact with the air and the similar variations in the activity of the discoloring agency in relation to variations in temperature.

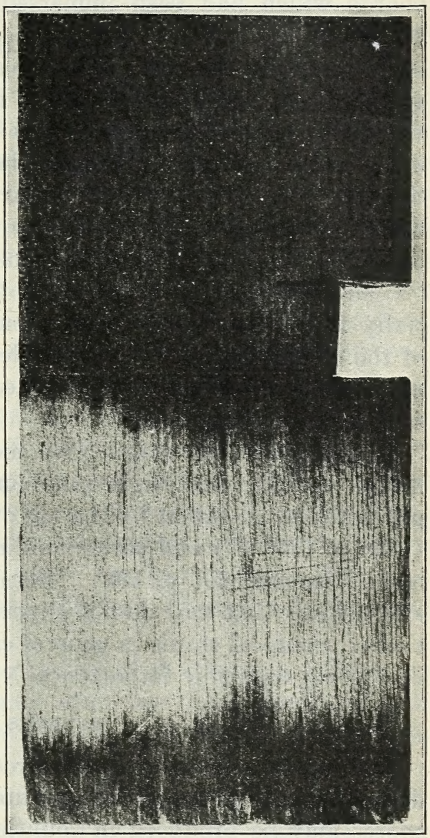


FIG. 1.—Board of sugar pine, showing chemical stain. The unstained area in the lower half of the illustration indicates the position of a crosser during the kiln treatment. The crosser afforded protection from oxidation. Photographed by H. D. Tiemann.

If discolorations in sapwood are due to the activity of oxidizing enzyms, which, as has been shown, are rendered inactive by exposure to a temperature of 100° C. (212° F.), a logical prophylactic measure would be the submersion of timber in boiling water. Bailey (*5*), during the spring of 1910, performed certain dipping experiments.

He found that when 1 by 3 by 6 inch boards of alder (*Alnus incana* Moench), white or gray birch (*Betula populifolia* Marsh), paper birch (*Betula papyrifera* Marsh), and various trees belonging to the rose family (Rosaceæ) were immersed in boiling water and then stacked under cover they would remain unchanged in color. Those boards which had been immersed in the boiling water and then placed in the most unfavorable conditions of high humidity and temperature in the open and exposed to the direct rays of the sun scorched on the surface. With the exception of this superficial scorching, no discoloration of the wood took place. On the other hand, untreated boards that had been cut from the same portion of the tree and subjected to similar conditions of temperature and humidity stained rapidly. Bailey (*5*) found that the rapidity and the depth to which the stain penetrates the wood varies with the temperature and the moisture, hot and humid weather being especially favorable for the production of stain. From a consideration of the results obtained, he concludes that sap-stain caused by oxidizing enzyms can be readily prevented by dipping the timber for a few minutes in boiling water.

Though chemical stains give more or less trouble in kiln-dried maple flooring and sugar-pine lumber, the discolorations may be prevented to an extent by the use of comparatively low temperatures (120° to 125° F.) and correspondingly low humidities (50 to 70 per cent; Tiemann, *51*, p. 185). Because of their limited distribution and the fact that they do not impair the strength or durability of the timber, chemical stains in general can hardly be considered as having very great economic importance.

FUNGOUS STAINS.

The second class of stains is produced by fungi. These fungi are disseminated by means of minute bodies known as spores. The spores may be produced in countless numbers and are blown about by the wind, washed along by the rain, or carried by animals, particularly insects. When, under favorable humidity and temperature conditions, they happen to lodge upon a substratum, such as the moist green sapwood of woods that contain the requisite food material, the spores may germinate and give rise to a mass of fine, usually septate threads, sometimes colorless at first, but often becoming darkened with age. This vegetative portion of the fungus is known as the mycelium, and the individual threads are called hyphæ. In some cases the hyphæ probably penetrate the wood but little, growing for the most part over the surface; in others, they may enter the sapwood through the medullary or pith rays. This does not result in the disintegration of the walls of the wood cells to any appreciable

extent. The starches, sugars, and oils stored in the sapwood and pith rays, together with the contained air and water, probably exert an influence upon the advancing hyphæ and limit largely the growth of the fungus to the sapwood and the pith rays, where the sap-stain is mainly to be found. Practically no invasion of the heartwood takes place (Von Schrenk, *41*, p. 19). (Pl. I, fig. 3.)

THE SAP-STAIN FUNGI.

The relation of a fungus to the bluing of wood was first noted by Hartig (*17*, *18*). He describes the organism which causes the so-called "bluing" of conifers, especially dead or dying pine that has been injured by caterpillars, as *Ceratostoma piliferum*. He notes that it may also appear in damp firewood. According to Hartig, the brown mycelium very quickly penetrates the trunk through the medullary rays. He states that probably on account of the deficiency in moisture content the heartwood is avoided by the mycelium, whereas the sapwood often becomes quickly invaded and decomposed. Although described by Fries (*13;* see also Berkeley, *6*), who placed it in the genus Sphaeria, the fungus was later transferred by Fückel (*14*; see also Ellis and Everhart, *10*) to the genus Ceratostoma. Saccardo (*39*) still later divided the genus Ceratostoma and placed those species which possess colorless spores in a new genus, Ceratostomella. Winter (*58*), in a subsequent revision of the family included the fungus as *Ceratostomella pilifera* Fries under the new genus. It is now known as *Ceratostomella pilifera* (Fries) Winter (Engler and Prantl, *29*).

Figure 2 illustrates the fruiting bodies of this fungus. With the aid of a magnifying glass one may often see them clearly as stiff black hairs, approximately 1 millimeter (1/25th of an inch) in length,[5] swollen at the bases, and forming, en masse, a dark hairy covering on the ends and tangential surfaces of stained sapwood. These growths when well developed are sometimes referred to by lumbermen as "whiskers."

Many species of Ceratostomella have been listed by Saccardo (*40*). Though no reference is made to the fact, it is probable that a number of these stain wood.

The life histories of many species of Ceratostomella found on stained wood have been worked out by Von Schrenk (*41*), Hedgcock (*19*), and Rumbold (*37*) in this country and by Münch (*31*) in Europe. In connection with the study of several chromogenic fungi which discolor wood, Hedgcock developed in culture a conidial stage of Ceratostomella superficially resembling Cephalosporium. Münch and Rumbold associated a Graphium stage with the development of

[5] In some species the length may exceed 2 millimeters.

Ceratostomella. During the extensive culture work of Hedgcock, however, extending over a period of four or five years and involving

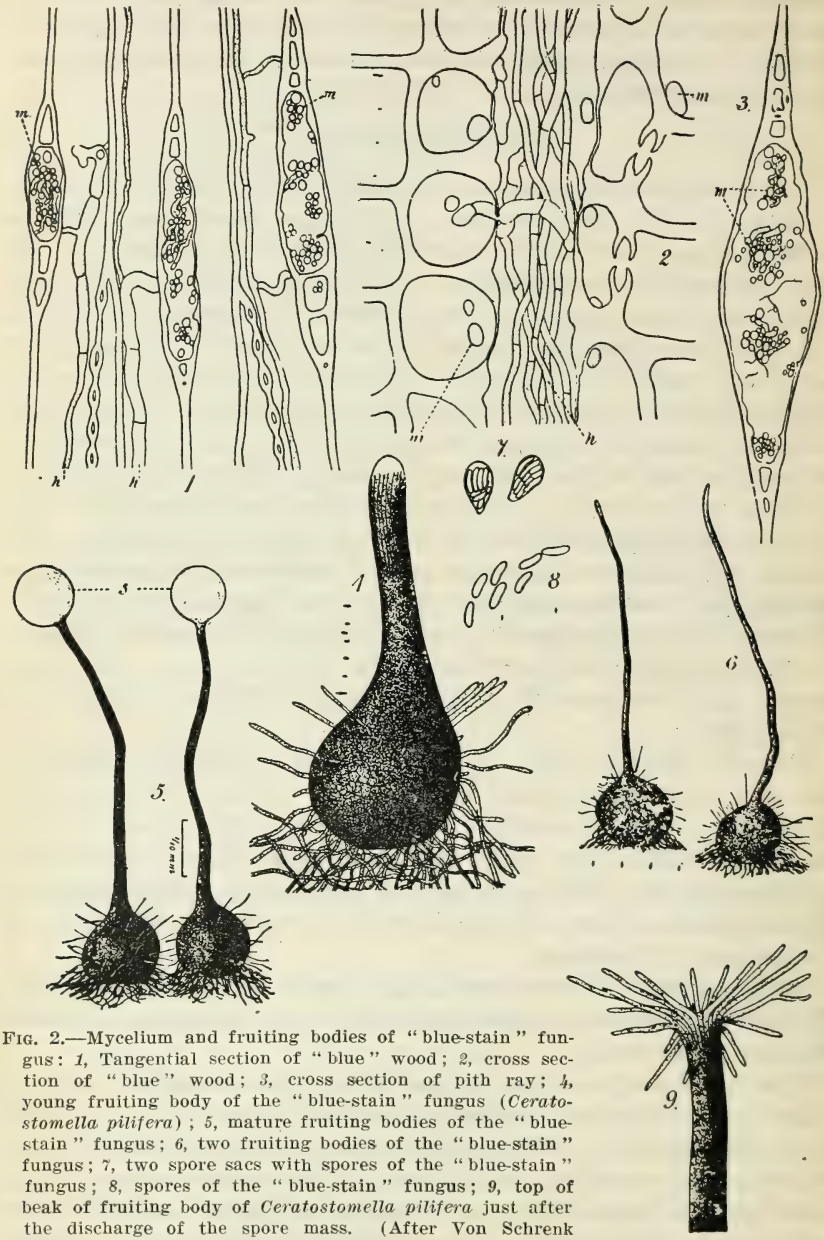
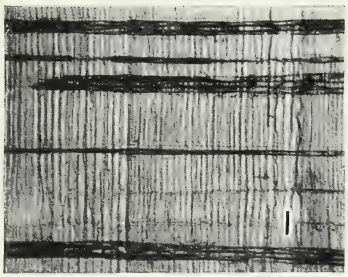
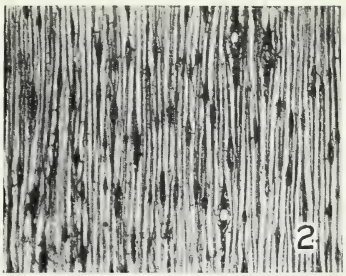
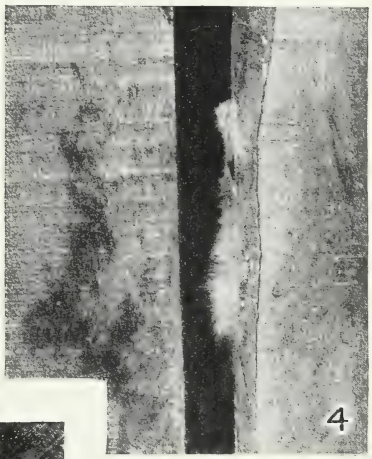


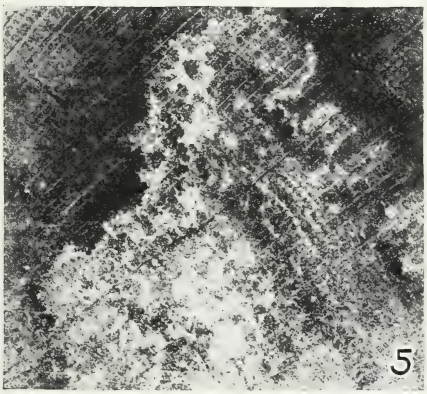
FIG. 2.—Mycelium and fruiting bodies of "blue-stain" fungus: *1*, Tangential section of "blue" wood; *2*, cross section of "blue" wood; *3*, cross section of pith ray; *4*, young fruiting body of the "blue-stain" fungus (*Ceratostomella pilifera*); *5*, mature fruiting bodies of the "blue-stain" fungus; *6*, two fruiting bodies of the "blue-stain" fungus; *7*, two spore sacs with spores of the "blue-stain" fungus; *8*, spores of the "blue-stain" fungus; *9*, top of beak of fruiting body of *Ceratostomella pilifera* just after the discharge of the spore mass. (After Von Schrenk (*32*), pl. 7.)

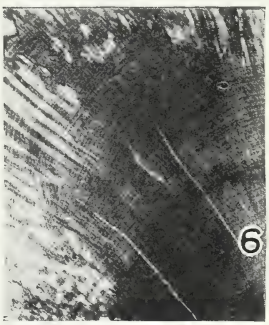
a number of species of Ceratostomella from a variety of sources, no Graphium stage of this fungus was ever reported.





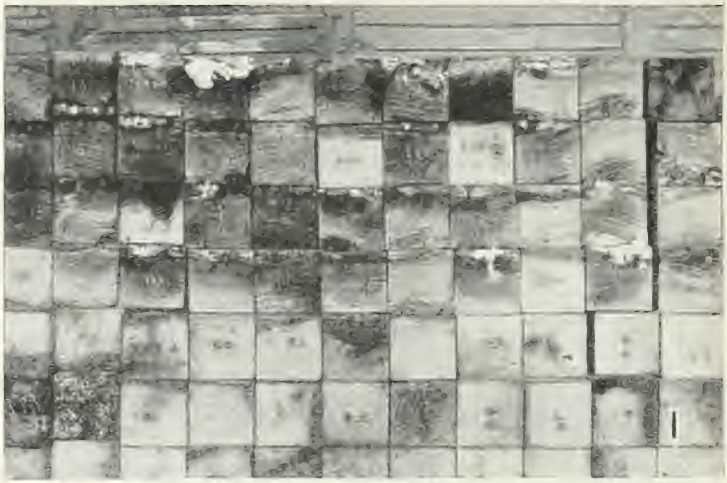


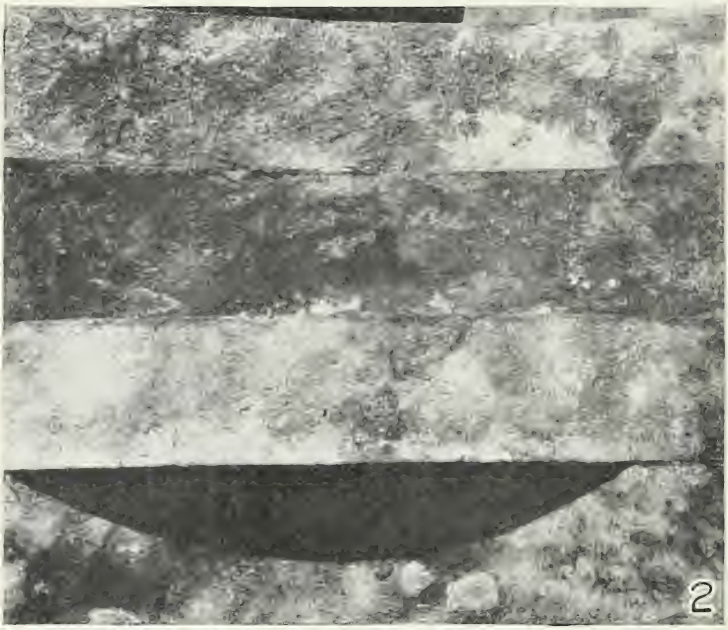




EXAMPLES OF WOOD INFECTION.—I.

FIG. 1.—Radial section of bull pine, showing hyphæ of the blue-stain fungus growing in the pith rays. FIG. 2.—Tangential section of the same, showing many small hyphæ growing into the adjoining cells. FIG. 3.—Log of southern yellow pine containing sap-stain. FIG. 4.—Mycelium of mold growing between hard-maple boards in a kiln. FIG. 5.—Mold on the end of a sawed red-oak billet. FIG. 6.—Maple billet containing sap-rot, a condition brought about through the agency of wood-destroying fungi. The surface has been polished to show more clearly the bleached and disorganized condition of the sapwood. (Figs. 1 and 2 are from Von Schrenk (*41*), pl. 8; fig. 4 is from a photograph by H. D. Tiemann.)





EXAMPLES OF WOOD INFECTION.—II.

FIG. 1.—Artificially infected blocks of red oak and white oak in the tile chamber ready for the steaming experiments performed at the Madison laboratory. The large white areas of mycelium on the ends of the blocks in the upper four rows are wood-destroying fungi and probably developed as a result of infection in the log. FIG. 2.—Sawed felloes of oak (species not known). Note the abundant growth of mold which had developed in the material during shipment and while in storage. Photographed by H. D. Tiemann.

Hedgcock (*19*) identified the following species of Ceratostomella as responsible for the discolorations produced in certain woods:

C. pilifera (Fr.) Wint., in the sapwood of several species of pine (Pinus), fir (Abies), oak (Quercus), and ash (Fraxinus).

C. schrenkiana n. sp., in short-leaf pine (*Pinus echinata* Mill.).

C. echinella E. and E., in freshly cut heartwood and sapwood of beech (*Fagus atropunicea* (Marsh) Sudworth).

C. capillifera n. sp., in wood of red gum (*Liquidamber styraciflua* L.).

C. pluriannulata n. sp., in blue sapwood of red oak (*Quercus rubra* L.).

C. minor n. sp., in Arizona pine (*Pinus arizonica* Eng.).

C. exigua n. sp., in dead and dying trees of scrub pine (*Pinus virginiana* Mill.).

C. moniliformis n. sp., in red gum (*Liquidambar styraciflua* L.).

Münch (*31*) split up *Ceratostomella pilifera* Fries into a series of new species, as follows:

1 *Ceratostomella pini*, the important blue-stain fungus of pine.

2. The pilifera group, distinguished by the secondary fruiting bodies:
   (*a*) *C. piceae*, with an associated Graphium stage, possibly *Graphium penicillioides* Corda, in species of pine and fir.
   (*b*) *C. cana*, with an associated but unclassified Graphium stage. This species he also found in pine wood.
   (c) *C. coerulea*, having no associated Graphium stage.

With these species of Ceratostomella Münch includes two unrelated fungi, *Endoconidiophora coerulescens* and *Cladosporium* sp., as causing discolorations in coniferous timber.[6]

Von Schrenk (*41*), in his studies of the "blue wood" in dead and dying stands of the western yellow pine (*Pinus ponderosa* Laws.), found that the spores of Ceratostomella blown about by wind or carried by insects are often deposited in the exposed ends left by the breaking of branches or in the holes made by the bark and wood boring beetles. There, under the favorable conditions which usually prevail, they germinate and readily produce in a short time many colorless, branching hyphæ. The hyphæ grow into the bark tissues, then into the cambium, and from there into the medullary rays. With age the hyphæ take on a brown hue.

According to Von Schrenk (*41*, pp. 18, 19), "one of the first effects seen after the hyphæ have entered the medullary ray cells is the gradual solution of the walls separating the medullary ray cells from one another (fig. 2, *1*, *2*, *3*). The walls which separate the ray cells from the neighboring wood cells may become very thin, as shown in the middle ray (fig. 2, *1*), but they are rarely dissolved entirely. The intermediate walls, on the other hand, entirely disappear. This

[6] In a recent publication, C. J. Humphrey (*23*) describes a fungus, *Lasiosphaeria pezizula* (B. and C.) Sacc., as the cause of a blue-black stain in certain hardwoods, particularly beech and red gum. More detailed information concerning this fungus, as well as certain species of Ceratostomella, is given by E. E. Hubert (*21*).

leaves a tube, with a cross section having the shape of the cross section of the ray, extending into the trunk from the bark. This tube is sometimes filled entirely with a mass of brown hyphæ, the larger number of which extend in the direction of the ray (Pl. I, figs. 1 and 2). From the ray cells some hyphæ make their way into adjacent wood cells (fig. 2, *2*; Pl. I, figs. 1 and 2).[7] They grow along these, both up and down (fig. 2, *1*), giving off branches to other wood cells. In this manner the whole wood body becomes penetrated by the brown hyphæ in a very short time after the first infection. The number of hyphæ in the wood cells proper, excluding the medullary ray cells and the cells of the wood parenchyma, is very small indeed. This is probably due to the fact that the fungus finds scant material upon which to live in the wood cells. The hyphæ are apparently able to puncture the unlignified walls here and there, but they stop at that point. The writer was not able to demonstrate that the hyphæ could attack the lignified walls. In other words, the 'blue' fungus is one which confines its attack to the food substances contained in the storing cells of the trunk and to the slightly lignified walls of these storing cells." According to the same authority (*41*, p. 19), the resin ducts may be attacked in like manner (fig. 2, *3*; Pl. I, fig. 2).

In the case of sawed timber it is quite probable that the fungous spores falling upon the surface of the sapwood find there the moisture and food material necessary for germination. Subsequently they give rise to a mass of mycelium, many of whose hyphæ enter the wood through the exposed medullary or pith rays and then probably invade the surrounding tissue, as explained by Von Schrenk.

SUSCEPTIBILITY OF VARIOUS WOODS TO SAP-STAIN FUNGI.

The sapwoods of many kinds of timber are susceptible to sap-stain, though the degree of susceptibility varies considerably. Among the conifers southern yellow pine, western yellow pine, sugar pine, and the spruces seem to be readily stained and in the case of the broad-leaved trees, red gum, red oak, white oak, and hackberry seem to be particularly susceptible.

Often there is a considerable difference between a species when grown on the dry uplands and the same species when grown under the moist conditions characteristic of the lowlands (Von Schrenk and Spaulding, *44*). This difference in woods of the same species may be even more marked when grown in essentially different climates (Spaulding, *48*). It seems to be the opinion of many lumbermen that timber grown in the South is more susceptible to fungous attacks than timber grown in the North. If differences in susceptibility do

[7] E. E. Hubert (*21*) observed in the wood of scrub pine and northern white cedar hyphæ of *Ceratostomella* sp., which had penetrated tracheids and wood fibers for a distance of several cells from the medullary rays.

exist in such woods it is difficult to state whether they are due to dissimilarities in mechanical structure, to the relative proportions of contained air and water, or to the variety and amounts of stored food present in the wood parenchyma and medullary rays. It is probable that differences in environmental conditions, i. e., temperature and humidity as affecting the growth of the fungi, are important factors directly responsible (Roth, *35*, p. 55–56).

STRENGTH OF "BLUED" WOOD.

Since the wood fibers are not appreciably impaired by the growth of the blue-stain fungus, there should be no apparent loss in the strength of the invaded wood. Rudeloff (*36*) found that the compression strength of pine is not affected by the presence of bluing fungi. Tests on the stained wood of western yellow pine conducted at Washington University, St. Louis, Mo. (Von Schrenk, *41*) and later at the Forest Products Laboratory, Madison, Wis. (Weiss, *56*; Weiss and Barnum, *57*) proved that there is practically no diminution in the end compression or cross-breaking strength and hardness of the stained as compared with the unstained wood. In the case of heavily stained shortleaf pine, however, tested at the latter institution, there was found to be a slight decrease in the strength, toughness, and hardness as compared with unstained wood having the same moisture content. It may be safely stated that blued wood is practically as strong as unstained wood.

CAUSE OF THE COLOR IN "BLUED" WOOD.

The cause of the blue color in the wood has never been satisfactorily explained. R. Hartig (*17*, p. 66) ascertained that it arises from the presence of the brown fungous hyphæ in the intercellular spaces. According to Von Schrenk (*41*, p. 18, 25–26), it appears in the wood when the colorless mycelium begins to take on the brown hue characteristic of the mature fungus. Microscopic examination of the wood fibers taken from the blued wood reveals no indication of a blue color. While extracts of the blue wood with alcohol, ether, benzol, chloroform, alkalis, and acids differ in appearance from those obtained from clear wood, yet no blue tinge is apparent. Von Schrenk (*41*, p. 26) suggests that possibly "there is some pigment with a blue element in the 'blue' wood which is so faint that its detection in thin microscopic sections becomes almost impossible." Hedgcock (*19*, p. 110–111) states that "the brown color of the fungus apparently contains traces of a blue pigment whose color is transmitted by the wood cells of the pine more readily than the brown color." Münch (*31*, p. 3) concludes that the color is due to the arrangement of the mycelial threads in the wood. He cites, as some-

what similar examples, the blue color of thin milk, cigarette smoke, and the clear sky, wherein very fine particles are held in suspension in a transparent medium.

OTHER FUNGOUS ORGANISMS CAUSING SURFACE DISCOLORATIONS IN GREEN TIMBER.

In addition to the blue-stain fungi, there is another group, the molds, which commonly occur upon the freshly cut surfaces of green timber when stored under moist, warm, and stagnant conditions (Pl. I, fig. 5; Pl. II, figs. 1 and 2). Molds are occasionally found growing vigorously upon timber in kilns (Pl. I, fig. 4). This is especially noticeable when the atmosphere of the kiln is exceedingly moist or saturated and the temperature ranges from 90° to 110° F.[8] or from 110° to 130° F. (Tiemann, *51*, p. 186–187).

FIG. 3.—Fruiting body of *Graphium* sp. (After Münch, *31*.)

Hedgcock (*19*) showed that the blackening and browning so common in the green sapwood of pine (*Pinus* sp.), poplar (*Populus* sp.), tulip (*Liriodendron* sp.), red gum (*Liquidambar* sp.), oak (*Quercus* sp.), maple (*Acer* sp.), and several other woods can often be traced to species of Graphium. He cites:

G. ambrosiigerum n. sp., on Arizona pine (*Pinus arizonica* Eng.).

G. eumorphum Sacc., on wild red raspberry (*Rubus strigosus*) and related species.

G. atrovirens n. sp., on red gum (*Liquidambar styraciflua* L.).

G. smaragdinum (A. and S.) Sacc., on red gum (*Liquidambar styraciflua* L.).

G. rigidum (Pers.) Sacc., on red oak (*Quercus rubra* L.).

G. aureum n. sp., on wh te pine (*Pinus strobus* L.).

G. album (Corda) Sacc., on beech (*Fagus atropunicea* (Marsh) Sudworth).

Graphium spp. are perhaps best known by the upright, cylindrical, occasionally branched fruiting bodies 1 to 3 millimeters in height (fig. 3). These are often brown to black in color and bear at the tips comparatively large and, in many cases, confluent globules composed of masses of spores embedded in a mucuslike substance. These spore masses, though usually cream color, vary somewhat in hue, and in some species are tinged with gray, brown, green, yellow, or red. While these are the organs of fructification commonly observed, other types less conspicuous and bearing the so-called secondary conidia have been demonstrated in culture by Hedgcock (*19*).

[8] Information from the section of timber physics, Forest Products Laboratory, Madison, Wis.

Other fungi mentioned by Hedgcock (*19*) as blackening wood are: *Alternaria tenuis* Nees., *Stachybotrys alternans* Bon., *Aspergillus niger*, *Chaetomium* sp., *Stemonitis* sp., *Gliocladium* sp., *Hormodendron* sp., *Hormiscium* sp., and *Cladosporium* sp. The apparent discoloration in these cases is due either to the presence of colored hyphæ in or upon the surface of the wood or to a luxuriant superficial growth of colored spore masses. In no case is it due to the secretion of any pigment which is absorbed by the wood.

Hedgcock (*19*) names three other species—*Penicillium aureum* Corda, *Penicillium roseum*, and a *Fusarium* sp. formerly included under *Fusarium roseum*—which, due to the secretion of soluble pigments, actually stain the wood red, purple, or yellow, according to the alkalinity or acidity of the medium. These stains are superficial, however, and readily dress off when the lumber is planed. Many other molds grow readily upon green sapwood and give the timber a displeasing appearance, though they cause no deterioration in the strength of the wood. From the material collected by the writer and sent to the Madison laboratory there have been isolated over 40 distinct species of fungi. With the exception of species of Ceratostomella and Graphium, together with a species of Fusarium which was identified by Dr. Mabel M. Brown, graduate student at the University of Wisconsin, as *F. arthrosporioides*, this number consists of fungi popularly known as molds. The determination of the molds was made by Dr. Charles Thom and Miss Margaret B. Church, of the Bureau of Chemistry, United States Department of Agriculture. They are listed below:

Aspergillus flavus series.
Aspergillus niger.
Aspergillus repens.
Aspergillus versicolor group.
Cephalothecium roseum.
Citromyces sp.
Cladosporium sp.
Clonostachys sp.
Gliocladium sp.
Haplographium sp.
Monilia sitophila.
Mucor sp.
Oidium sp.
Penicillium asperulum or *puberulum.*
Penicillium brevicaule series.
Penicillium commune.
Penicillium divaricatum.
Penicillium lilacinum.
Penicillium luteum.
Penicillium purpurogenum.
Penicillium roqueforti.
Penicillium rugulosum.
Penicillium solitum.
Syncephalastrum sp.
Trichoderma sp.

The great variety of genera and species here noted contains many earth dwellers and indicates that the molds commonly found upon green timber, especially during storage and transit, are for the most part soil forms whose spores have by accident fallen upon the moist surfaces of the sapwood and there found the conditions favorable for development.

It has generally been supposed that the growth of mold on wood is confined mainly to the surface or, at the most, to the superficial

layers, perhaps a few cells in thickness. H. Marshall Ward (*55*), however, in connection with certain experiments upon spruce blocks which had been artificially infected with *Penicillium* sp., notes that the examination of sections from cultures 3 months old showed that the hyphæ of this fungus had entered the starch-bearing cells in the medullary rays of the sapwood and had consumed the starch. The hyphæ were observed deep in the wood extending from tracheid to tracheid through the bordered pits. Miss A. L. Smith (*46*) notes the presence of a dark-brown hyphomycete in decaying timber. This mycelium had invaded the woody tissue and had apparently brought about a partial destruction of the medullary rays (see also Freeman, 12).[9]

During a series of experiments by the writer, cultures were taken from various points within red-oak blocks 2½ by 2½ by 10 inches long which had been cut from green sapwood and then artificially infected with 15 different fungi including 13 of the common molds.[10]

The results obtained seem to confirm Ward's experiments, for positive mold cultures were secured even from the center of these blocks. However, as far as known, the molds do not cause any serious disintegration of the cell walls in green timber and thus do not impair the strength of the wood to any appreciable extent. As in the case of the blue-stain fungus, it is the stored food within the cells that is the object of attack.

The principal objection to the presence of mold lies in the discoloration due to the masses of mycelium and the luxuriant clusters of fruiting bodies which often develop upon green sapwood, and sometimes the heartwood, under conditions of high humidity and temperature resulting from poor ventilation. However, these superficial growths are readily removed during sanding or planing operations. In many cases they can be readily brushed off. This is particularly true of material which has become surface dried.

An inspection of a carload of moldy timber is quite likely to produce an impression that is liable to react unfavorably upon the shipper. Moreover, the presence of much mold or sap-stain in timber indicates the existence of conditions which are favorable to the development of decay. Such material, then, should be viewed with suspicion, but not of necessity with unfavorable discrimination.

FACTORS WHICH FAVOR THE GROWTH OF SAP-STAIN AND MOLD FUNGI.

The development of fungi is dependent upon four factors—a supply of air, containing the essential element oxygen; the requisite

[9] McBeth and Scales (*30*) list a considerable number of molds that are apparently able to destroy cellulose, though they act differently toward different kinds of cellulose.

[10] See page 29 for the list of fungi used in this experiment.

amount of moisture; a temperature range within certain limits; and the necessary food substances.

Air.—Fungi require oxygen for their growth. This is supplied as one of the constitutents of ordinary air. Even under storage conditions the supply is ample. Stagnant air containing a considerable amount of moisture is favorable to the growth of fungi in the timber, in that it prevents the drying of the wood. Timber entirely submerged in water is practically immune from fungous attacks, since the supply of oxygen is cut off.

Moisture.—The extent of the growth of sap-stain and mold fungi is largely dependent upon the amount of moisture present in the substratum. This moisture content in green timbers of different species as well as in the sapwood and heartwood of a particular species may vary considerably. Thus, according to Tiemann (*51*, p. 106; *33*, tables), the green sapwood of conifers may contain from 100 to 150 per cent moisture,[11] while the heartwood, probably being near its fiber saturation point, contains about 30 per cent. In the case of the hardwoods, both heartwood and sapwood may contain from 60 to over 200 per cent moisture. Frequently, however, there is present a greater quantity of free water in the sapwood than in the heartwood (Tiemann, *51*). In air-dried timber the amount of moisture may be reduced to anywhere from 8 to 18 per cent, according to the climate. In kiln-dried material it may be reduced to 3 to 15 per cent moisture, depending upon requirement and uses. This will explain why mold and sap-stain, so frequently found in green timber, are absent in thoroughly air-seasoned or kiln-dried stock. Air currents will often surface-dry the timber to an extent that will make it practically impossible for fungi to grow thereon.

The relative quantities of water and air found in the wood, according to Von Schrenk (*43*), are the most important factors in the control of the rate of growth and spread of the sap-stain fungus. He cites Münch's experiments (*32*) on artificially inoculated pine blocks,[12] differing only in the relative amounts of contained water and air. These experiments seem to indicate that the growth of the fungus is inhibited when the normal winter water content of the wood is raised to an amount that will insure a consequent reduction in the volume of contained air to at least 15 per cent, based on the volume of the fresh wood. According to Münch (*32*) an air content of 42 per cent, brought about through a reduction of the normal winter water content of the wood, is the optimum for development of the fungus in the wood. Münch (*31*, p. 59–62) states that the sap-stain fungus at-

[11] Unless otherwise stated, all percentages of moisture content are based upon oven-dry weight.

[12] The blocks in this case were artificially inoculated with the conidia of *Ceratostomella coerulea.*

tacks recently felled trees, but does not penetrate deeply, owing to the high water content of the wood. He also states that the mycelium of the fungus readily penetrates throughout the sapwood of winter-felled wood when the loss in water content amounts to 10 to 20 per cent. Moreover, the growth in moist wood takes place for the most part in the older layers of the sapwood, or those in proximity to the heartwood. Finally, Münch concludes that the sap-stain fungus is capable of infecting the living tree, thus becoming parasitic, provided the fungous spores find entrance to the sapwood through injuries to the bark, such as those produced by bark-boring beetles; and that conditions favorable for fungous growth, namely, a reduction in the water content and a corresponding increase in the air content of the sapwood, are brought about through disturbances in the root system of the tree.

In this connection certain investigations by Snell (*47*) on the relation of the amount of decay to the density of the wood should be mentioned. Five fungi which had been found to cause the rotting of structural timber in New England cotton mills were grown upon blocks of loblolly-pine sapwood and Sitka spruce. Several series of these blocks, each series containing a different percentage of moisture, were used in these experiments. The results obtained with loblolly pine agreed in the main with those of Münch (*32*) upon Scotch pine, a wood of about the same density. In the case of Sitka spruce, a wood of considerably less density, however, it was found that the limits of moisture content favorable for fungous growth were raised. In other words, "the values representing the upper limits for decay will vary inversely with the density of the wood."

Temperature.—It has been clearly demonstrated in a number of temperature tests [13] upon some of the molds derived from infected timber that these fungi grow readily between certain limiting temperatures. Beyond these, they cease to show any signs of activity. The optimum temperatures are commonly those which obtain during the late spring and summer months in certain parts of the country, particularly in the South, i. e., 80° to 85° F. It is probable, however, that each species has its own characteristic range.

Food.—Sap-staining fungi and molds have been shown in cultures to live upon quite a variety of foods. Being devoid of chlorophyll they can not, like the higher plants, manufacture their own food, but must depend upon that already available. The medullary rays and wood parenchyma of green sapwood often contain certain starches, sugars, and oils which represent the stored food of the tree. These are the substances upon which sap-staining fungi probably depend for their existence.

[13] These tests were conducted at the Forest Products Laboratory, Madison, by Mrs. Rose Harsch Lynwalter.

When supplied with the essentials necessary for growth, fungi develop rapidly and often reproduce abundantly. Deprived of any or all of these factors, however, the vegetative portion, i. e., mycelium, ceases to grow and eventually dies. In some cases, as, for instance, certain molds, the spores may retain their vitality for long periods under extremely unfavorable circumstances. When favorable conditions return, these spores soon germinate and often develop an abundant growth of mycelium within a few days. Fruiting bodies, sometimes bearing countless spores, may then make their appearance, and the life cycle is repeated. The ideal conditions for growth are often to be found in green timber containing a high percentage of sapwood when exposed to the stagnant atmosphere of the woods, poorly ventilated sheds, warehouses, and cars during warm, sultry, or rainy weather. Under such circumstances the sapwood may become thoroughly infected within a few days. Sap-stain may thus appear soon after infection with spores or mycelium of the sap-stain fungi. Wood-rotting fungi may also get a good hold upon timber under such conditions, and symptoms of incipient decay later become apparent (Pl. I, fig. 6).

DURABILITY OF STAINED OR MOLDED WOOD.

Since the blue stain and mold fungi cause little or no dissolution of the wood fibers, they do not affect directly the durability of the timber. If properly piled and dried, stained or moldy wood stock free from decay should not deteriorate further from the action of the fungi. However, the conditions which favor the development of sap-stain, mold, and sap-rot are much the same, namely, the presence of spores or mycelium of the particular fungi capable of producing these defects in wood, a substratum containing the requisite food material, moisture, and a high relative humidity (75 to 100 per cent), a temperature of 70° to 100° F., and a lack of circulation of the air, or stagnation, which retards or prevents the proper drying of the timber. There seems to exist among many lumbermen a false notion that mold and sap-stain represent early stages in the development of sap-rot, or "dote," as it is commonly called. While the presence of an abundant growth of mold or sap-stain in green stock indicates conditions which are likely to favor the growth of rot, it is well known that the rot is caused by a distinct group of true wood-destroying fungi which develop independently.

Molds in general develop rapidly. Hence, they may be often found growing profusely on green timber already infected with rot-producing fungi long before the latter have exhibited any noticeable evidence of their presence. It is possible, however, for wood destroyers to infect and bring about the disintegration of wood which contains no trace of mold or any other organisms.

LOSSES DUE TO SAP-STAIN OR MOLD.

INSANITARY PRACTICES IN THE HANDLING OF GREEN WOOD STOCK.

As a result of investigations in the woods, inspections of many carloads of green timber and dimension stock upon arrival at the mill, examinations of green and seasoned manufactured stock upon arrival at the vehicle factory, and talks with practical millmen and lumbermen, the writer is convinced that a considerable amount of the damage to vehicle stock, due to fungi, is brought about through the use of infected raw material. Many of the infections take place in the woods, as a result of insanitary practices in the handling of logs, bolts, and split billets. In many instances, during warm and humid weather logs and bolts have been allowed to lie in the woods for weeks. Under such conditions sap-stain is almost certain to follow. Moreover, the liability to attack by wood-destroying fungi is greatly increased.

Split billets, instead of being cross piled on dry foundations, are sometimes thrown carelessly about the stump and left until a convenient time for hauling arrives. Under favorable circumstances it takes but a few days for certain fungi to gain a good hold on such stock, and unless later checked or destroyed by some process such as kiln drying, they may produce a permanent stain or decay in the sapwood.

It is quite probable that a serious shortage of cars suitable for handling the logs, bolts, and billets may prevent at times the rapid movement of raw stock to the mills. This results in the accumulation of material in the woods and railroad yards and contributes to conditions in many cases favorable to the development of the fungi. Frequently box cars are used where in normal times the more open and consequently better ventilated types of car would be employed.

Failure to observe proper measures during storage, such as the use of dry foundations for logs and bolts, the cross piling or stripping of billets on dry foundations sufficiently high to give suitable ventilation from beneath, and the storage of stock in properly ventilated sheds, has furnished conditions suitable for the development of mold, sap-stain, and decay in such material.

A few millmen seem to have the mistaken idea that an abundant growth of mold on green stock serves to protect it from checking by preventing evaporation from the surface of the wood and actually absorbing, or possibly condensing, moisture from the surrounding atmosphere and then transmitting it to the wood. The fungus derives its moisture from the wood, not the air. Its presence, however, often indicates a high humidity in the immediate vicinity, a condition which prevents the drying of the wood and thus favors the growth of fungi. It is quite probable that the phenomenon known as gutta-

tion, i. e., the collection of minute drops of excreted water upon the fungous growth, is responsible for the misconception.

In some instances split billets upon being unloaded from the cars are thrown in a pile beside the track, sometimes upon damp soil, there to remain for perhaps a month or until opportunity can be found for removal to storage sheds. Losses due to fungi are a natural consequence of such treatment.

It has taken time for those unaccustomed to the handling of green stock to work out satisfactory methods which would provide proper ventilation of dimension, sawed, or turned stock during transit. Meantime, many shipments have been seriously damaged. Of the different forms of stock, the sawed billet, the rim strip, and plank have given the most trouble. Losses are not confined to such stock, however, for turned spokes and hubs, unless properly safeguarded during transit, are liable to stain and mold.

Sawed billets often arrive at the factory in a badly stained condition. It is probable that material containing fungous infections sometimes finds its way into their manufacture. The squared surfaces lend themselves to close piling and thus to the formation of masses wherein sufficient ventilation is impossible. Rim strips also frequently become badly stained while in transit, as a result of the same causes, together with the fact that some manufacturers require such stock to be close piled in closed box cars and even sprayed with water to prevent checking. It is unfortunate that the conditions necessary for the prevention of checking in green stock are as a general rule favorable to the growth of fungi, and vice versa.

ECONOMIC IMPORTANCE.

The presence of much sap-stain and even mold in timber is considered by some lumbermen as a defect. Therefore, degrading of material thus affected, with consequent loss in monetary value, may result. Such unfavorable discrimination is due to the notion that stained or moldy material is not as sound as clear stock. In the case of molds, it is an easy matter to remove the surface blemish by the simple process of sanding or planing. With sap-stain, however, the removal of the discoloration depends entirely upon the depth to which the mycelium has penetrated. In some cases the stain may extend to the heartwood. It is evident that it can not under such circumstances be removed by the processes referred to.

The presence of much stain will prevent the use of timber for purposes where color, texture, and clearness of grain are of prime importance. Basket and box veneer, interior finish, flooring, and furniture stock which are to have no protecting coat of paint must be free from stain. Discrimination, however, should not be made

against sap-stained or moldy stock that is to be covered, provided there is no incipient decay associated with it.

The reduction in the value of stained lumber sometimes amounts to $2 or more per 1,000 feet, board measure, and perhaps one-fourth of the annual mill cut of the United States is attacked. In one year it was estimated that the total losses from sap-stain amounted to between 8 and 9 million dollars (Weiss, *56*; Weiss and Barnum, *57*; see also Pratt, *34*). The amount in any locality, however, depends upon the climate, the season, and several other factors.

Weather conditions have a marked influence upon the amount of damage to freshly cut timber in the woods or to green stock in storage and in transit. During warm and moist weather such stock will sometimes stain badly and in a short time, unless it is properly safeguarded. This, of course, is due to the fact that the warm and humid conditions stimulate the development of the fungi. It follows, then, that the greater losses from sap-stain, sap-rot, or mold should be expected during the warmer months, and especially during those months in which both high temperatures and high humidity normally prevail. As a matter of fact, this is the case. In the months of April, May, June, July, and sometimes August and even September, depending upon climatic conditions, the greatest damage occurs. In the South, owing to the prevailing high temperatures and relative humidities, the losses are often extremely severe. The greatest losses occur in low-grade coniferous lumber, especially the southern pines, owing partly to the high percentage of sapwood and partly to the fact that the low-grade lumber is seldom kiln dried, but is stacked in the yard to air season. Under such circumstances, unless unusual precautions are observed, it is very liable to the attacks of the sap-stain fungi.

From replies to the questionnaires sent out by the wood-stock committee to contractors and producers of wood stock regarding sap-stain and mold in vehicle stock and from the data derived from the personal investigations of the writer, it was learned that these losses are dependent largely upon the manner in which the stock is piled in the cars and sheds during transit or storage. The losses average less than 10 per cent, but may reach from 25 to 75 per cent. The writer was informed that because of such damage to green spokes during the summer of 1918, sometimes as many as 50 per cent in a carload lot were culled. When turned spokes were selling at $150 per 1,000 feet b. m., the loss on a carload containing perhaps 12,000 escort spokes, $2\frac{1}{2}$ by $2\frac{1}{2}$ by 27 inches, was evidently considerable, perhaps amounting to hundreds of dollars. One firm reported that it had knowledge of entire carloads being destroyed. In some instances cars had gone astray and had finally reached their proper destina-

tion after one or two months on the road. Losses in those cases were often practically complete. Sixteen different firms reported that for the year 1917 their individual losses due to "heating in transit," as staining is sometimes explained by lumbermen, varied from $100 to $5,000. One company reported the losses as varying from $25,000 to over $75,000 in different years.[14]

CONTROL MEASURES.

A great many attempts have been made to devise measures for the control of sap-stain and mold in green timber. With the exception of kiln drying, however, none of these has proved entirely satisfactory. When tried under circumstances unfavorable to the growth of fungi, some of these measures have met with considerable success, but when put to the test under conditions which stimulate fungous development, they have often failed. For the most part they have been prophylactic rather than curative in nature. However, it is believed that many of the following measures, although not entirely effective, will assist materially in reducing losses due to sap-stain, mold, and incipient decay in green stock.

HANDLING IN THE WOODS.

AUTUMN AND WINTER CUTTING.

Many lumbermen (*15*) think that, where possible, timber should be cut in the autumn and winter. While this is probably true, the reason often given is incorrect. The statement is usually made that winter cutting is better because the "sap is down." It has been shown by T. Hartig (*33*, tables; Janka, *26*) that during the spring when the growth is most active the tree sometimes contains less water than in the winter. It is probable that the changes in moisture content which do take place are confined mainly to the sapwood. It is true that the movement of sap is much more rapid at the time of active growth and that there are important chemical changes which take place therein during the different seasons of the year. In the winter, insoluble starches and gums are stored in the sapwood. During the spring these are changed to soluble sugars and are borne through the living tissues. The sapwood of summer-cut logs, therefore, contains soluble foods which render it extremely susceptible to attacks by fungi during the warm months when these organisms are most active. Winter-cut logs, on the other hand, have an opportunity to season under conditions less favorable for fungous growth and by the time warm weather

[14] National Implement and Vehicle Association and other Vehicle and Vehicle Parts Manufacturers. Information Division of the Wagon and Vehicle Committee and the Wheel Manufacturers' War Service Committee. Wood Stock Committee. Sap-stain and mold in transit. Nat. Implement and Vehicle Assoc., etc., Bul. 30, 5 p. 1918. A. B. Thielens, chairman. Typewritten.

arrives will have dried to a degree which will render them less susceptible to fungi (Roth, *35*, p. 57).

In the bottom lands of the South, however, autumn and winter cutting may not always be feasible owing to the wet and muddy conditions then prevailing, which make hauling difficult, if not impossible.

Incidentally, leaf seasoning (Tiemann, *51*), i. e., girdling trees while in full leaf and then allowing them to remain, often for years or until the leaves have entirely shriveled up, with the idea that much of the free water in the sapwood will be drawn off by transpiration through the leaf surfaces and thus prevent sap-stain, does not seem to be practiced in the regions visited by the writer. Although this method is said to be common in the seasoning of teak in India and has been advocated by some as applicable to gum in this country, yet it does not seem to meet with general approval, because it exposes the timber to the ravages of insects and to fungi causing decay.

RAPID HAULING.

One of the precautionary measures to be observed, especially during the late spring and summer, is that of hauling timber immediately after felling. Raw stock can not be gotten out of the woods and to the saw too rapidly. It is possible for fungous infections to take place at all times of the year on the exposed surfaces of freshly cut timber. These develop more rapidly, however, during warm, humid weather, and especially under the conditions which obtain in the woods.

STORAGE IN THE WOODS.

If it is found necessary to allow logs and bolts to remain in the woods, they should be so separated that the ends are left several inches apart. If the sawed ends remain in contact, fungi are liable to develop between them. Some have recommended that logs that are to remain in the woods during the summer be painted on the exposed ends with creosote (Von Schrenk, *42*). It has been considered advantageous by some (Von Schrenk, *42*; see also Hartig, *18*) to remove the bark from logs that must of necessity be left in the woods for an extended period. Advocates of such treatment state that the peeled surfaces soon become air-dried and consequently provide insufficient moisture for the germination of any fungous spores that may fall thereon. In order to keep such logs off the damp ground and thus assist in the air-drying process measures must be taken to provide some sort of temporary foundation free from stain, mold, or rot.

When it becomes necessary to store split billets in the woods, they should be piled with only two billets in a course and should rest upon

a foundation located on dry ground and consisting, where possible, of billets of split heartwood free from rot.

HANDLING RAW STOCK IN TRANSIT.

TYPES OF CARS.

In shipping green stock to be used in the manufacture of vehicles, etc., the following types of cars have been preferred:

Flat cars.....logs (fig. 4).
Gondolas or stock cars.....bolts (fig. 5).
Stock or vegetable cars.....split billets or dimension stock.
Ventilated box cars.....lumber or dimension stock.

FIG. 4.—Unloading logs from a flat car. This is the type of car usually used for the shipment of logs.

PROVISIONS FOR THE PROPER VENTILATION OF STOCK IN TRANSIT.

Well-ventilated types of cars should be selected where possible, if staining and molding are to be prevented (figs. 4 to 10). Preparatory to use, these cars should be thoroughly swept free from rubbish, damp sawdust, lime, or manure. In the case of box cars, it is important that the roofs be carefully inspected to make sure that they are water-tight. If it becomes necessary to use box cars for the transportation of split billets during the late spring and summer months, it is suggested that the billets be ricked and that strips or occasional crossers of the same stock at intervals of 12 to 16 inches be used to assist in the ventilation of the pile. Side doors should be open and both doorways boarded up, leaving at least 1½-inch spaces between the boards. If box cars are equipped with small

end doors of the ventilating type, these doors should be left open and the doorways cleated to prevent the stock from working out during transit. Lumber shipped in box cars must be stripped.

HANDLING RAW STOCK IN THE YARDS.

STORAGE OF LOGS AND BOLTS.

When piling or cording logs and bolts in the yard for storage, it is important that they be kept off the ground by the use of clean skids or permanent foundations of seasoned fungus-free planks, stone, or cement. Such foundations should be placed on well-drained soil free from underbrush or weeds that might interfere with proper ventilation from beneath.

FIG. 5.—Bolts loaded in a gondola car. Gondolas, stock, or vegetable cars are best adapted to the transportation of this type of raw stock.

STORAGE OF BILLETS.

Billets that are not turned at once should be stored upon dry foundations and in properly ventilated sheds (fig. 11). When sufficient storage space is available, the method of piling used by one of the large wheel manufacturers in the North, shown in figure 12, is recommended.

STORAGE OF GREEN LUMBER.

The methods of piling lumber are pretty well understood and need little explanation here (*7*).[15] In general, it is well to select a location

[15] For information concerning this point, the reader is referred to Bulletin No. 552, United States Department of Agriculture (7), copies of which may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents per copy.

on well-drained soil free from weeds and one which will allow the prevailing winds to blow through the sides rather than upon the ends of the stacks.

Care should be taken to provide suitable foundations consisting of metal or well-seasoned heart stock, preferably creosoted and resting upon piers of creosoted wood or, better, of stone, brick, concrete, or metal. All foundations should be sufficiently high to allow for ventilation vertically through the stacks. Moreover, there should be ample space between the stacks to permit a free circulation of the air around them. Finally, it is important that narrow strips, perhaps 1 inch wide and at least 1 inch thick, of well-seasoned, kiln-dried, or chemically treated wood be used between all courses and that they be carefully placed in vertical alignment to prevent warping of the stock.[16]

FIG. 6.—Bolts piled in a box car. Note the débris on the floor of the car. Bolts are likely to suffer from fungous attacks when shipped in box cars with the doors closed.

HANDLING AT THE MILL.

EARLY MANUFACTURE.

Logs, bolts, and split billets should be sawed into dimension stock or planks and manufactured as soon as possible. This will do much toward safeguarding the material by reducing the time in storage.

AIR SEASONING.

Provided kilns are not available, the dimension stock should be seasoned from six months to a year or more, depending upon the

[16] The general sanitation of lumber yards and the proper methods to be observed in the piling of timber to prevent or reduce losses in storage due to fungi, together with a consideration of the more common rot-producing organisms, are clearly described by Humphrey (22), in Bulletin No. 510, United States Department of Agriculture. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 20 cents per copy.

size and kind of material.[17] When sufficiently dry, shipments in closed box cars will suffer little or no loss from sap-stain or mold. In all cases where air seasoning is resorted to, unless great care is exercised in providing for ample circulation of air through the stock by such means as open piling, fungous and insect troubles are likely to develop. It is absolutely necessary to strip or cross pile the stock upon dry foundations. For purposes of stripping, kiln-dried or chemically treated strips 1 inch wide and at least 1 inch thick should be used between courses. All sheds for the storage of this material should be dry and well ventilated.

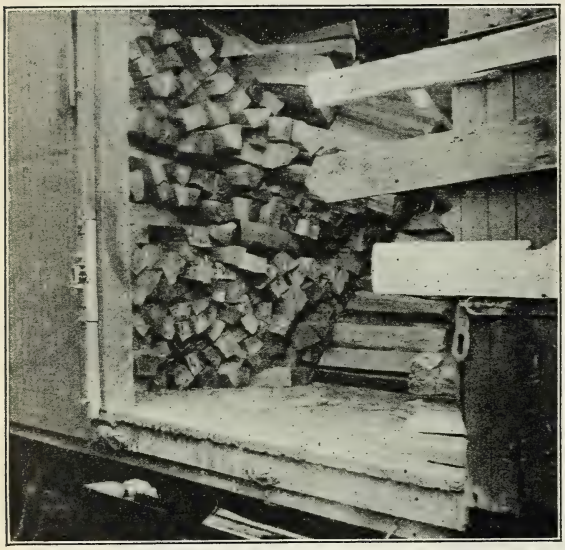


FIG. 7.—Split billets piled in a box car. When occasional billets are used as crossers and the doors of the car are cleated open this type of spoke stock suffers but little while in transit.

KILN DRYING.

By far the most effective and quickest method of treating green stock, as a prophylactic measure, to destroy fungi or insects and to reduce shipping weight, is to subject the material to proper kiln drying. When producers are equipped with, or have access to, modern kilns operated on a scientific basis and are so situated that stock can be moved rapidly, less concern need be given to fungous troubles. Kiln-dried spokes can be bundled or close piled in dry warehouses or in ordinary box cars and shipped without loss.

Material kiln dried directly from the saw has been shown to be just as good as air-seasoned stock (Tiemann, *51*, p. 300) and in many cases much better as far as strength, toughness, and freedom from defects are concerned. Moreover, the time necessary for seasoning can often be reduced from one year to three weeks or from three to five years to as many months.

[17] The reader is again referred to Department Bulletin No. 552 (7) for information concerning the seasoning of wood.

Kiln drying reduces shipping weight; makes the lumber fit for almost immediate use; eliminates or reduces losses due to insects,[18] or to checking, rotting, staining, or molding; improves the quality of the lumber; reduces the amount of yard space; and saves the tying up of capital and carrying costs (Tiemann, *51*, p. 4, 5).

It is possible that where several producers are located within a few miles of one another, a battery of modern dry kilns, operated according to the most approved methods (possibly on the community plan) might solve the problem of cost of installation and operation.

In dry kilns, stripping or cross piling the stock and providing means to prevent stagnation of the confined air are absolutely necessary if the development of mold is to be avoided. The water spray kiln devised at the Forests Products Laboratory represents one of the latest developments in the temperature and humidity-controlled type of kiln.[19]

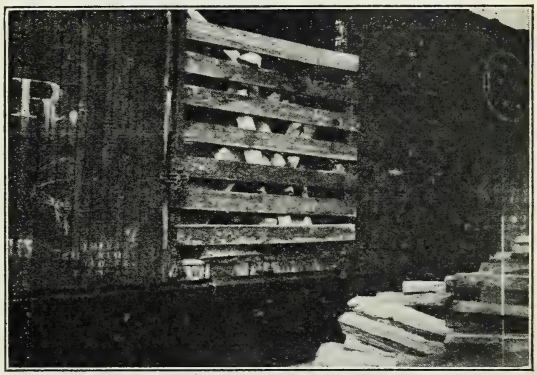


FIG. 8.—Split billets loosely piled in the areaway between the doors of a box car. The doorways are loosely boarded up to allow for ventilation of the car and at the same time prevent the stock from working out while in transit.

During the first few weeks of kiln drying, when the humidity is high and the temperature ranges from 80° to 105° F., an abundant growth of white mycelium occasionally forms between the courses and interferes more or less with the circulation of the air in the kiln. This is due to the presence of mold fungi, and it usually indicates stagnation in the kiln (Pl. I, fig. 4). Steaming for one hour at a temperature of 160° to 180° F. has been found effective in destroying or at least checking the growth of this mold (Tiemann (*51*), p. 187).

[18] Powder-post beetles, however, are said to cause considerable damage at times in seasoned stock; in fact, these beetles do not work in green stock.

[19] A complete description of this kiln is given in Bulletin No. 509, United States Department of Agriculture (*52*), a copy of which may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 5 cents. Further information concerning the design and installation of this kiln is given in Bulletin No. 894, United States Department of Agriculture (*50*), to be procured from the same source at 10 cents a copy.

STEAMING GREEN STOCK AS A CONTROL MEASURE.

METHODS COMMERCIALLY EMPLOYED.

Steaming certain kinds of stock (green gum lumber, birch hubs, spokes, and sawed felloes of red or white oak) is sometimes resorted to as a means of reducing shipping weight by hastening drying or to even up the color and reveal defects in the wood.

In the steaming of green gum lumber a large steel tank, or preparator, is employed. The lumber loaded upon trucks is run into this preparator and steamed for perhaps 15 to 30 minutes at pressures of 20 to 30 pounds (figs. 13 and 14). Provided this lumber is then carefully open piled, it remains clean. When close piled or when exposed to adverse weather conditions, however, it may mold almost as readily as untreated green lumber.

FIG. 9.—A box car loaded with split billets upon its arrival at the spoke mill. The method of loosely boarding the doorway, as shown in figure 8, is preferable in that there is less danger of the stock working out while in transit. When, however, the masses of billets are held in position by supports, or when vertical boards are nailed a few inches back of the cleats, this method may be used. Both provide for the ventilation of the stock.

Hubs, sawed felloes, and turned spokes green from the saw are sometimes steamed at atmospheric pressure. At one plant visited, green birch hubs were stacked in large cement boxes and subjected to exhaust steam for 24 to 36 hours, depending upon the size of the hub. At the end of that time the steam was shut off and the hubs were allowed to cool for perhaps 10 hours. The hubs were then carried to a ventilated warehouse and stacked, zigzag fashion, to provide for ample circulation of the air through the inside as well as around them. In this manner an even drying was secured. Two to three weeks was considered a sufficient length of time for the necessary air drying previous to shipping. During the warmer months, stock cars were used as means of transportation.

The steaming of gum and birch is a comparatively simple process. But in the case of woods that check readily, such as oak, this treatment requires considerable care.

THE EXPERIMENTAL STEAMING OF RED-OAK AND WHITE-OAK BLOCKS AT THE LABORATORY OF FOREST PATHOLOGY, MADISON, WIS.

During the spring of 1919 the writer performed several series of experiments at the Madison laboratory to determine the efficiency of steam at atmospheric pressure in destroying mold and sap-stain fungi in artificially infected red or white oak blocks $2\frac{1}{2}$ by $2\frac{1}{2}$ by 10 inches. Incidentally the rate of drying and the amount of checking were noted in connection with the steaming.

The blocks were sawed from the sapwood of summer-cut logs, weighed, and then sprayed with a water suspension of spores taken from cultures of mold fungi originally derived from infected material sent in by the writer. A list of the fungi used in these experiments follows:

Aspergillus flavus.
Aspergillus niger.
Cephalothecium roseum.
Ceratostomella sp.
Citromyces sp.
Graphium sp.
Monilia sitophila.
Mucor sp.
Penicillium asperulum.
Penicillium divaricatum.
Penicillium luteum.
Penicillium pinophilum.
Penicillium rugulosum.
Syncephalastrum sp.
Trichoderma sp.

FIG. 10.—Square billets close piled in a box car. This type of raw stock suffers considerably when piled in the manner shown here. Stripping or cross piling while in transit or storage is essential if losses from fungi are to be avoided.

The sprayed blocks were then placed in a tile chamber, which served as an incubator. After several weeks in this chamber, where an average relative humidity of 95 per cent and an average temperature of 70° F. prevailed, the blocks became well infected and developed countless numbers of the fruiting bodies peculiar to the fungi mentioned above (Pl. II, fig. 1).

A steam box was constructed of cypress, equipped with thermometers, dew-point apparatus, and manometer and connected with the main which supplies steam to the laboratory greenhouse (figs. 15 and 16). By means of suitable reducing valves in the connecting pipes it was possible to control the steam pressure in the box; hence, the exact conditions to which the blocks were subjected could be readily determined. Steam at atmospheric pressure only was used.

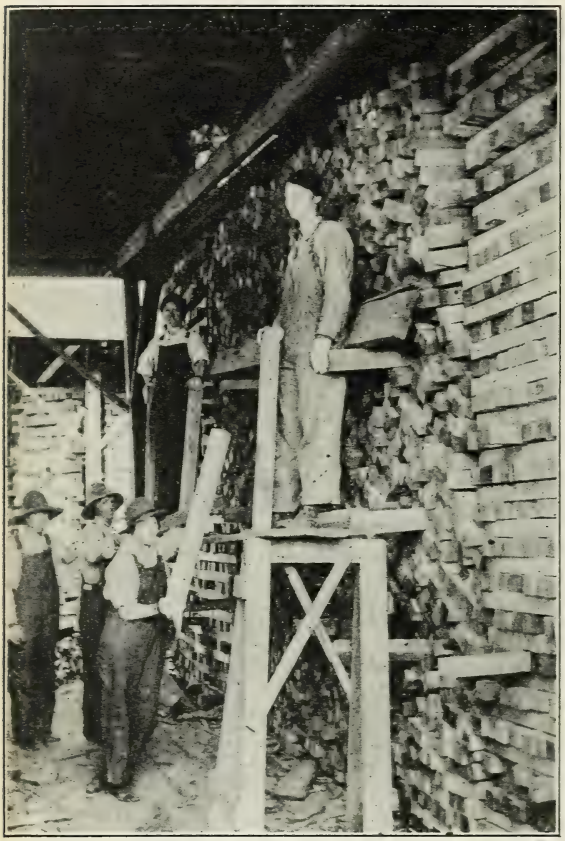


FIG. 11.—Stacking sawed billets in an open shed. It will be observed that the billets at the extreme right are cross piled, while those in the center are close piled. The former method of piling insures a better ventilation of the stack, provided intervals of at least 1 inch are left between the adjacent billets of a course. In the case of the cross-piled billets shown here this provision was not made.

Previous to steaming, the blocks were again weighed. They were then close piled or stripped in groups of 25 in the steam box and steamed for different lengths of time. At the end of the steaming period, some of the lots were allowed to cool for a certain time and then reweighed. Others were weighed immediately. Nearly all were put in a small ventilated box in the open and allowed to air-dry for several weeks. Some, however, were placed in a closed shed for four weeks, and still others were taken from the steam box, weighed, and placed directly in the tile chamber. Some lots were stripped; others were close piled. An interval of at least 3 inches was maintained between adjacent piles.

After the preliminary seasoning mentioned above, a number of the blocks were returned to the tile chamber for incubation. This was done for the purpose of subjecting the blocks to the conditions existing in box cars and poorly ventilated warehouses during warm and

sultry weather. The tile chamber, when given a preliminary treatment, which consisted of intermittent steaming for three successive days to reduce the amount of viable fungous growth therein, provided these conditions admirably. In this chamber the temperature was maintained at an average of 85° F., while the relative humidity varied from 70 to 95 per cent. At the end of four weeks in the tile chamber the blocks were removed and their condition with respect to molding noted.

The following observations were made from several series of experiments:

The amount of drying which took place in the steam box was comparatively slight. This seemed to depend, however, upon the relative moisture content of the wood previous to steaming. Green blocks usually lost, while partly seasoned blocks often gained in weight.

Beyond a certain length of time, dependent upon the moisture content of the wood and the surface area of the blocks in relation to volume, there seemed to be little gained, in so far as the reduction in weight was concerned, by continued steaming. Six or nine hours' steaming seemed to be no more efficient than three hours in the case of the 2½ by 2½ by 10 inch blocks.

FIG. 12.—Diagram illustrating one method of stacking green split billets. This method is used by one of the large wheel factories of the North. When ample storage space in well-ventilated sheds is available, this method is recommended.

Steamed blocks subsequently dried more rapidly than those that were simply air-dried.

Open piling or stripping in the steam box was preferable, in that it permitted a better circulation of the steam in the box and thus insured a more uniform treatment of the blocks.

The amount of checking varied in the several lots when steamed under the same conditions. This may have been due to the fact that the blocks differed considerably in the relative proportion of sapwood and heartwood present.

The greatest amount of checking occurred in those lots that were subjected to rapid cooling and surface drying by exposure to air currents from open doors and ventilators. Blocks allowed to cool in the steam box with doors closed seemed to suffer least in this regard. Slow cooling was, in some cases, brought about by opening a small hatch in the roof of the steam box at the conclusion of the steaming period.

The total amount of checking which had taken place in the steamed blocks, both during the steaming process and the subsequent period of air seasoning, extending over four months, exceeded but little that noted in those blocks which had been simply air seasoned for the same length of time.

Steaming seemed to be effective in killing the fungi in the infected blocks when employed for a period of three hours. Cultures taken from various points

in or upon the blocks by means of a sterile scalpel and needle gave no growth, while cultures taken from check blocks which had not been steamed gave positive results in every case.

Steamed material, unless open piled under conditions which insured an ample supply of circulating air, molded almost as readily as green stock.

Steamed blocks that were given a month's air drying subsequent to steaming and previous to storage under the extreme conditions that prevailed in the tile chamber showed a little more resistance to the invasion of fungi than those blocks that were placed in the tile chamber immediately after steaming.

It is quite probable that the steam treatment of wood stock, followed immediately by prolonged submersion of the material in some of the antiseptic solutions to be described later, might prove to be a

FIG. 13.—Boards of red gum loaded on a truck and ready to be rolled into the preparator (shown in fig. 14).

fairly effective method for the control of fungi in infected stock. This treatment might be applied to special classes of wood stock where the margin of profit would justify the extra cost.

THE CHEMICAL TREATMENT OF GREEN WOOD STOCK.

Many attempts have been made to find some chemical compound or mixture that, when applied as a dip, will control sap-stain and mold in green timber. A great many substances have been tried, but none have proved entirely satisfactory. Under conditions not particularly favorable to the growth of fungi, several have met with considerable success. On the other hand, if the conditions were stimulating to fungous growth, the same substances often failed. Some treatments depend for their efficiency upon the neutralization of the acids in the wood and, at the same time, the establishment of

alkaline conditions. To this group belong sodium carbonate, sodium bicarbonate, sodium hydroxid, lime, and borax. Others are intended to poison the food of the fungi, and comprise such compounds and mixtures as mercuric chlorid, copper sulphate, sodium fluorid, creosote, and many other substances.

Toxicity tests (Humphrey and Fleming, *24*)[20] conducted at the Madison laboratory upon a few molds commonly occurring upon infected timber, as well as upon several wood-destroying fungi, have clearly demonstrated that when the entire culture medium is permeated with these and many other preservatives, often in very small amounts, the growth of the fungus can be readily inhibited. Hence,

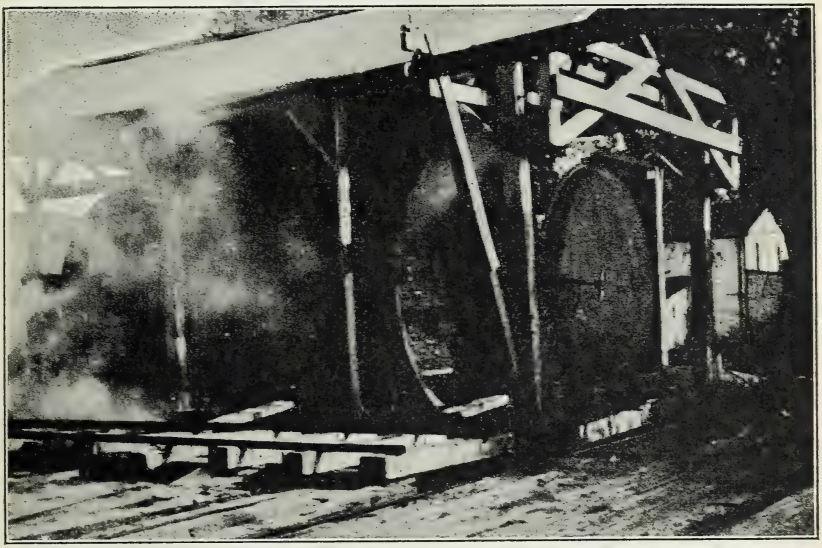


FIG. 14.—Preparator used for the commercial steaming of red-gum lumber at one of the mills in Arkansas.

if wood be thoroughly impregnated with a solution of one of these common preservatives it will be protected from decay as well as from sap-stain and mold.

This is quite possible in the case of thoroughly seasoned timber impregnated with preservatives by subjection to high pressure in closed retorts. The penetration of green timber by cold solutions of salts in an open tank or by the brush treatment, however, is extremely slight.[21] Tests made by the writer for the presence of copper in the interior of $\frac{3}{4}$ by $\frac{3}{4}$ by $1\frac{1}{2}$ inch blocks sawed from the green

[20] Information also obtained from unpublished reports of toxicity experiments performed by Miss C. Audrey Richards at the Laboratory of Forest Pathology, Madison, Wis.

[21] For a description of the pressure, open-tank, and brush treatments, the reader is referred to Forest Service Bulletin No. 78 (*45*) and to Farmers' Bulletin 744 (*25*), U. S. Department of Agriculture.

sapwood of red oak and then dipped for 10 seconds in solutions of copper nitrate and copper sulphate at ordinary temperature showed that these solutions had penetrated the ends of the blocks for a distance less than 5 millimeters (one-fifth of an inch) and scarcely a measurable amount in the case of the tangential or radial surfaces. It is evident, then, that whatever value there is in the use of cold dipping solutions lies entirely in the superficial coating of the preservative left upon the wood. Provided this is not brushed off or washed off by rain, it may inhibit or prevent the germination of fungous spores which happen to fall upon such surfaces. Hot solu-

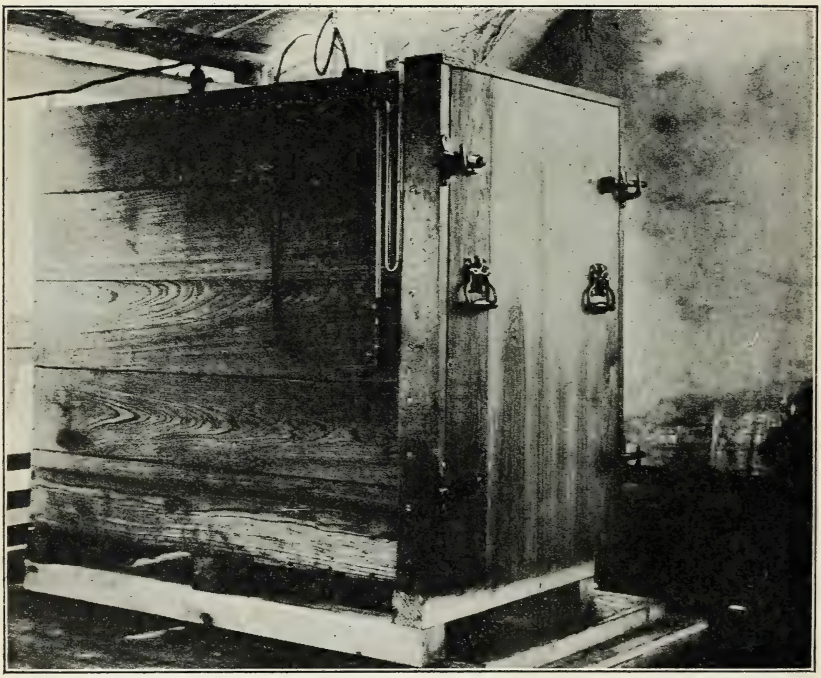


FIG. 15.—Steam box of cypress used in the experimental steaming of red-oak and white-oak blocks at the Madison laboratory.

tions, in that they tend to prevent the collection of bubbles of air upon the surface of the wood, probably give a more uniform distribution of the preservative over the dipped material. As far as penetration is concerned, however, it is doubtful whether the hot solutions, as ordinarily employed, possess any very great advantages. A slightly increased penetration may be secured by first subjecting the stock to a thorough steaming or by heating it for some time in a hot solution of the preservatives, as in the open-tank process. The air within the cavities of the wood is thereby expanded, and some escapes. Provided the steamed or hot wood is at once transferred to a cold solution of the preservative and there allowed to remain till

cool, an amount, approximately equal to the original volume of the escaped air, will be forced into the wood. This is a slow process, however, and therefore somewhat expensive.

The rate of evaporation of the liquid, in the case of hot solutions, is much greater than in cold solutions; hence, it becomes necessary to take frequent hydrometer readings of the bath and to make the proper adjustments in the relative proportions of the solvent and dissolved substances in order to maintain a uniform concentration.

Dipping may be of some value when applied to stock free from fungi. In those cases where the fungi are already in the timber, however, it is doubtful whether very much good can result from chemical dips unless the material be subjected first to a relatively high temperature and for a length of time sufficient to destroy these organisms.

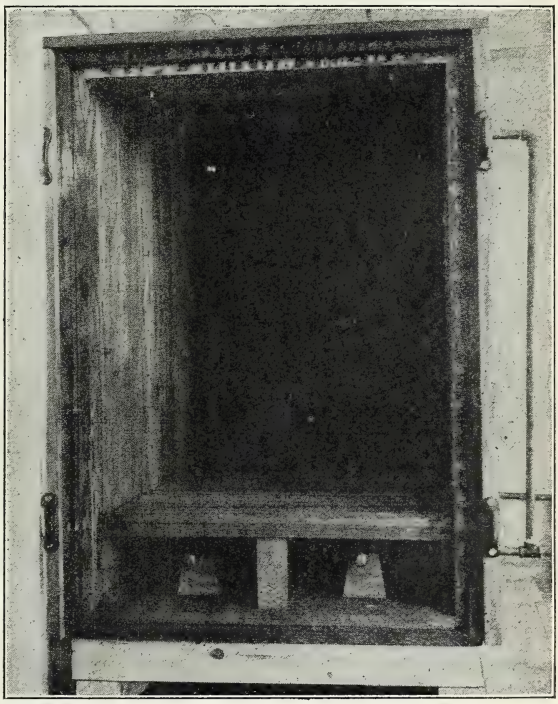


FIG. 16.—Details of the interior of the steam box used in the experimental steaming of red-oak and white-oak blocks at the Madison laboratory.

The salts used in the chemical treatment of lumber are likely to vary considerably in strength and purity. It is probable that the lack of uniformity in the results obtained by different investigators when employing nominally the same compounds may be traced partly to this cause. A few of the preservatives commonly used are described here.

SODIUM CARBONATE AND SODIUM BICARBONATE.

The substances which have been most frequently employed to prevent sap-stain in lumber are sodium carbonate (commonly in the form of soda ash) and sodium bicarbonate (baking soda). Solutions of these salts are applied either hot or cold by dipping in an open tank. On southern yellow pine, when used in concentrations of 4 to 5 per cent sodium carbonate and 5 to 6 per cent sodium bicarbonate, these

substances have given more or less satisfactory results (Weiss and Barnum, *57*). In wet weather, however, it has been found necessary practically to double the strength of the solutions. Moreover, both sodium carbonate and sodium bicarbonate cause a yellow to brown discoloration of the wood. Lumber treated with these preservatives must be open piled or it may mold and stain badly during warm, humid weather.

A good grade of sodium carbonate in the form of soda ash should contain 58½ per cent alkali, while the amount present in sodium bicarbonate (baking soda) is about 37 per cent. Solutions of the latter are more or less decomposed at temperatures above 158° F., giving off carbon dioxid. In a series of laboratory experiments followed by practical field tests on southern yellow pine and red gum, Rumbold (*37*) found that the blue-stain fungus is sensitive to alkalis but not to acids, that an 8 per cent solution of sodium carbonate is as effective as an 11 per cent solution of sodium bicarbonate, and that the amount necessary to prevent growth varies with the substratum. Freshly cut sapwood of southern yellow pine or red gum required 8 per cent sodium carbonate and 10 per cent sodium bicarbonate solutions under conditions which were especially favorable for the growth of the blue-stain fungus. In dry weather a weak solution of the alkali (a 5 per cent solution of sodium carbonate and a 4 per cent solution of the bicarbonate) kept the yellow pine boards free from stain. It was also observed that the spores of the blue-stain fungus are more resistant than the mycelium. These experiments seem to show that sodium carbonate and sodium bicarbonate possess some value as a preventive against sap-stain but that the success attending the treatment is largely dependent upon weather conditions.

SODIUM FLUORID, SODIUM BIFLUORID, AMMONIUM FLUORID.

Sodium fluorid, which has proved to be very toxic to wood-destroying fungi (Teesdale, *49*), has also been tested to determine its toxic properties in connection with the blue-stain fungus. Representatives [22] of the Forest Products Laboratory, working independently and in cooperation with certain lumber mills located in Mississippi and Louisiana, found that both sodium fluorid and sodium bifluorid were effective against sap-stain. The fluorids have an advantage over sodium carbonate and sodium bicarbonate in that they do not discolor the timber. One of these investigators, in a comparative series of experiments with a number of preservatives, including 2½ per cent sodium fluorid, 2½ per cent sodium bifluorid, and 2½ per cent ammonium fluorid, found that in the concentrations mentioned these salts were fairly effective against sap-stain. The ammonium fluorid,

[22] Unpublished reports by Pettigrew and Knowlton in the files of the Forest Products Laboratory, Madison, Wis.

in addition, seemed to be of some value in controlling mold. However, both of these series of experiments were performed during hot and dry weather—conditions unfavorable to fungous growth; hence, it is impossible to draw satisfactory conclusions from the results.

While the fluorids may be effective in controlling decay and, to a certain extent, stain-producing organisms, they can not be depended upon to prevent molding.

MERCURIC CHLORID.

Probably the best antiseptic to prevent sap-stain and mold in green wood stock is mercuric chlorid. When used on coniferous woods and on many of the hardwoods in concentrations of 0.1 per cent to 1 per cent, it has been found to be exceedingly efficient. The addition of 0.1 to 1 per cent hydrochloric acid is said to increase its stability. Mercuric chlorid, however, is extremely poisonous when taken internally. Many individuals show a marked susceptibility to the poison even when applied externally. Moreover, the solutions of mercuric chlorid are corrosive to iron, zinc, and many other metals commonly employed in dipping vats. For these reasons it can not be recommended for general use.

SOME RESULTS OBTAINED FROM THE USE OF ANTISEPTICS BY VARIOUS INVESTIGATORS.

It is probable that the efficiency of a given antiseptic varies considerably when applied to woods of different species and at various stages of air seasoning. As stated before, the results are likewise dependent upon climatic conditions. On open-piled boards of shortleaf pine in Missouri, Von Schrenk, Bessey, and Spaulding found that 5 per cent sodium bicarbonate or one-twentieth per cent mercuric chlorid gave good results (Hedgcock, *20*). On open-piled white pine in Wisconsin, the first two investigators found that the solutions giving the best results were 5 per cent borax and 2.5 per cent sodium bicarbonate, while on boards of Norway pine in open piles 5 per cent borax, one-twentieth of 1 per cent mercuric chlorid, and 2.5 per cent sodium bicarbonate were most effective (Hedgcock, *20*). As the result of experiments on longleaf pine boards in open piles at Bogalusa, La., Weiss and Barnum (*56*, *57*) concluded that the most effective antiseptics for the control of sap-stain, in that wood at least, are mercuric chlorid in concentrations of 0.1 to 1 per cent and sodium bicarbonate in strengths varying from 5 to 10 per cent. In these experiments 5 per cent borax gave poor results.

Hedgcock (*20*), in connection with certain experiments at Baltimore, Md., on the prevention of mold and stain in veneer baskets made from poplar, sycamore, beech, gum, and maple, found that the most effective solutions were 10 per cent sodium carbonate, 6.5 and 10 per cent sodium bicarbonate, 2.5 per cent sodium bicarbonate plus

0.66 per cent borax and boric acid, 0.20 per cent sulphur plus 0.20 per cent lime, 0.10 per cent mercuric chlorid plus 0.20 per cent hydrochloric acid, 10 per cent potassium (alum), and 0.33 per cent phenol salicylate. He concludes that of these substances, 5 to 10 per cent sodium bicarbonate is the safest and best to use.

In nearly all the cases cited the antiseptics proved to be of some value in preventing the growths of the sap-stain fungus. Molds, however, are extremely resistant to chemical treatment and consequently are difficult to control. To quote from Lafar (*28*): "Whether the waterproof character of some cell membranes, e. g., the conidia of Penicillium and Aspergillus, should be attributed to

FIG. 17.—Barrels and steam-coil connections as used in the experimental dipping of red-oak spokes at one of the large spoke mills in the South.

the deposition of excreted fatty or waxy substances must be left undetermined. Biologically this phenomenon is important, since it prevents the penetration of toxic substances from the aqueous medium and thereby also opposes the attempts of the mycologist to kill such fungi by means of aqueous toxic solutions." Since, as has been stated repeatedly, molds develop largely on the surface of the timber and are sufficiently removed during the several finishing processes to which the timber is sooner or later subjected, their presence in most cases should occasion but little concern in connection with vehicle stock.

EXPERIMENTAL DIPPING OF RED-OAK SPOKES.

DIPPING.

In July, 1918, several series of experiments were performed by the writer in cooperation with one of the large spoke mills of the

South. It was desired to test in a more practical way some of the antiseptics that had been used on a small scale during preliminary experiments at the Madison laboratory. In these experiments first-grade escort spokes 2½ by 2½ by 27 inches long of red oak were used. They were selected mainly for two reasons: First, red oak in a green condition was the wood, of all those used at this particular mill, which seemed to be the most liable to mold and sap-stain; second, the escort spoke was convenient to handle in connection with the dipping apparatus employed.

All spokes were taken directly from the warehouse after turning and grading. It was noted that 80 to 90 per cent of them contained sapwood varying in amount from 5 to 100 per cent.

In lieu of dipping tanks it was decided to use whisky barrels of 50-gallon capacity. Three of these were placed on a platform in the mill yard beside the tracks upon which the trucks were operated. One barrel was equipped with a steam coil of bent ½-inch iron pipe provided with shut-off valves (fig. 17). This coil, when connected with the main steam boiler, supplied the necessary heat for maintaining the temperature of the dipping solutions. A piece of corrugated, galvanized-iron plate, approximately 2 by 6 feet, when supported in a slanting position with the lower end resting upon the top of the barrel, served as a drain board. Iron tongs similar to those used by blacksmiths, hydrometers, thermometers, and a gallon measure completed the list of essential apparatus.

The following antiseptics were applied in the form of solutions or in a dry state:

(*a*) Barrett's grade 1 liquid creosote, 10 per cent by volume.
Perfection kerosene oil, 90 per cent by volume.
Temperature, 80° to 90° F.

(*b*) Barrett's grade 1 liquid creosote, 10 per cent by volume.
Perfection kerosene oil, 90 per cent by volume.
Temperature, 150° to 155° F.

(*c*) Powdered borax, 5 per cent by weight.
Water, 95 per cent by weight.
Temperature, 80° to 90° F.

(*d*) Mercuric chlorid (C. P.), 1 per cent by weight.
Hydrochloric acid (commercial), 1 per cent by weight.
Water, 98 per cent by weight.
Temperature, 80° to 90° F.

(*e*) Dry salt (finely grained).

(*f*) Dry quicklime (finely powdered).

The spokes were conveyed to the dipping barrels on trucks. There they were grasped by means of the iron tongs, immersed from 5 to 10 seconds in the bath, and then placed on the corrugated-iron drain board (fig. 18). When practically all of the excess liquid had drained off they were again grasped with the tongs, loaded upon another truck, and wheeled to the north end of one of the open sheds

in the yard. There they were unloaded, close piled, and allowed to remain until ready for shipment.

During the dipping operation it was observed that in some cases as many as 10 to 15 per cent of the untreated spokes in a given truck load showed the presence of sap-stain. In one lot the number showing sap-stain and mold was estimated at 50 per cent. Other lots were practically free from fungi. During the experimental work the weather was for the most part hot and dry. Following one or two light showers the amount of mold on untreated material showed a marked gain.

The methods of dipping were similar for all baths except in the case of the hot creosote. Here, the steam coil was employed and a

FIG. 18.—The experimental dipping of red-oak spokes green from the lathe.

temperature of 150° to 155° F. maintained. One barrel served for both cold and hot creosote. The borax was dissolved by aid of the steam coil in the second barrel. A third barrel was necessary for the mercuric-chlorid dip. Thermometer and hydrometer readings were taken at frequent intervals, and whenever necessary corrections were made to maintain a constant temperature and concentration in the bath.

Incidentally, it was noticed that ambrosia beetles were very quickly killed by the creosote dip, a point of importance to consider in controlling insect pests which at times, especially during warm and damp weather, are said to cause considerable losses in piled lumber.[23] (Weiss, *56*, p. 18–20.)

[23] A certain species of beetle, *Dendroctonus ponderosae* Hopk., has been mentioned by Von Schrenk (*41*) as being partly responsible for the dissemination of the spores of the blue-stain fungus.

Both cold and hot solutions of creosote may cause considerable irritation, and in some cases blistering, when brought in contact with the skin. By proper use of the tongs, however, this trouble was avoided. Rubber gloves were worn during the dipping of spokes in the solutions of mercuric chlorid, since that salt, as already stated, is a deadly poison when taken internally and is sometimes absorbed through the skin when solutions are handled continuously.

Many metals, such as iron and zinc, possess the common property of precipitating metallic mercury from the solutions of its salts. For this reason the iron tongs and other metallic objects could not be used in connection with the mercuric-chlorid dip.

The spokes that were treated with salt or lime were placed, a few at a time, in wooden boxes containing the respective substances in a finely powdered state and were rolled to distribute the chemicals over them as evenly as possible. The excess was shaken off. They were then close piled in one section of the warehouse. After 24 hours the lime coating showed a marked tendency to absorb moisture and cake. Moreover, it turned the wood dark. For this reason the liming was discontinued after 300 spokes had been treated. The salted spokes soon became exceedingly moist, due to the hygroscopic nature of the salt. The antiseptics used and the number of spokes treated in the different lots follow:

(*a*) 10 per cent creosote in kerosene, cold	5,100
(*b*) 10 per cent creosote in kerosene, hot	5,100
(*c*) 5 per cent borax in water	1,013
(*d*) 1 per cent mercuric chlorid plus 1 per cent hydrochloric acid	1,000
(*e*) Dry salt	1,032
(*f*) Dry quicklime	300

The first lot went forward in a box car loaded to capacity with 5,000 cold-creosoted spokes, 5,000 that had been hot creosoted, 800 spokes that had been dipped in mercuric chlorid, and 350 that were untreated. It was originally intended to ship the other lots at the same time. The car, however, was found to be too small, so the borax-treated, salted, and limed spokes went forward at a later date.

Many of the cold-creosoted spokes that had lain in the shed for two to three weeks awaiting shipment were slightly molded. It was noticed that those with the mold were taken from that part of the pile that had suffered most from poor ventilation, namely, near the bottom and in the rear. The spokes in the other lots at that time seemed to be free from mold or sap-stain.

METHOD OF LOADING CAR NO. 1.

The spokes were stacked in transverse ricks, beginning at the end of the car and working toward the doorway. Each rick was built up in the following manner. A row consisting of five pairs of spokes

all parallel to the length of the car was laid across the floor. An interval of perhaps 1 or 2 inches separated the members of a pair, and the distance between successive pairs was made a little less than the length of a spoke. Upon either end of these was laid a single transverse row of spokes. A third layer similar to the first and a fourth similar to the second were then laid down. With two more alternate layers a comparatively open base six layers in height and providing for partial aeration of the ricks was constructed. Upon this base the remaining spokes of the rick were close piled in successive layers, two or three spokes in depth. Each alternate horizontal layer was placed at a slight angle to those directly above and below, but all had a general direction lengthwise of the car. Each rick when built to within 2 feet or so of the roof contained on an average 833 spokes. As soon as one end of the car had been filled ricks were placed in the opposite end. In the doorway three longitudinal ricks were constructed and any space remaining was filled in with loose spokes. In this particular case one end of the car was stacked with the hot-creosoted spokes, the opposite end and $1\frac{1}{3}$ ricks in the doorway being stacked with the cold-creosoted spokes. Parts of two ricks in or near the doorway comprised spokes treated with mercuric chlorid, and the remainder consisted of untreated spokes thrown in loosely between the longitudinal ricks and the doorway. Both doorways were boarded up with 6-inch boards spaced $1\frac{1}{2}$ inches apart, and both doors were left open for about 1 foot. This car left the yard on July 24, consigned to one of the large vehicle factories of the North and reached its destination on August 14. On August 15 and 16 it was unloaded and inspected by C. J. Humphrey and the writer. During the time that the car was in transit the weather was in general hot and dry, although local showers may have been encountered.

CONDITION OF SPOKES IN CAR NO. 1 UPON ARRIVAL AT DESTINATION.

The inspection at the time of arrival was very thorough, each spoke being handled separately and a record kept of the number showing mold in any degree. Observations were also made, in a general way, of the extent of sap-stain and incipient rot. No attempt was made to discriminate between heavy and light infections, as these largely depended, with a given preservative, on the position of the spokes in the ricks or in the car with respect to the amount of ventilation received. In general, the top layers to a depth of 15 to 18 inches showed very little mold; likewise, the loosely arranged bases were quite free or comparatively so. The molds consisted for the most part of fluffy white to tawny mycelium, together with a comparatively small amount of green Penicillium. In the case of the cold-creosoted spokes, there seemed to be an increase over the amount

which was observed on the same spokes at the time of loading. For convenience in presentation, the data relative to location in the car and condition are given in Table I.

TABLE I.—*Condition of the red-oak spokes in car No. 1 upon arrival at its destination.*

Location in car.[a]	Antiseptic.	Condition.	Percentage molded (based on 833 spokes per rick).
Forward end of the car:			
Loose in the doorway.	Untreated	Free from mold or sap-stain; a few badly checked.	.....
Stacked in the doorway and first rick.	Mercuric chlorid and hydrochloric acid.	None with mold or sap-stain; not so many checked as in the untreated lot.	.....
First rick	Hot creosote at 150° to 155° F.	None with mold; no sap-stain	.....
Second rick	do	68 with mold; no sap-stain	8.2
Third rick	do	431 with mold; no sap-stain	51.7
Fourth rick	do	277 with mold; no sap-stain	33.2
Fifth rick	do	218 with mold; no sap-stain	26.2
Sixth rick (end of the car).	do	222 with mold; no sap-stain	26.7
Opposite end of the car:			
Stacked in the doorway and first rick.	Cold creosote at 80° to 90° F.	69 with mold; no sap-stain	8.3
Second rick	do	492 with mold; no sap-stain	59.1
Third rick	do	348 with mold; no sap-stain	41.8
Fourth rick	do	207 with mold; no sap-stain	24.8
Fifth rick (end of the car).	do	142 with mold; no sap-stain	17.0

[a] Ricks are in each case numbered from the first transverse rick on either side of the area between the doors and extending back to the ends of the car.

It will be seen from Table I that the spokes that were placed in the doorway where better ventilation could be had did not mold or sap-stain. Those that were the most exposed, however, were inclined to suffer from checking. The largest proportion of molding took place in the second or third ricks, but in no case was this accompanied by sap-stain, and in no instance was it severe enough to necessitate culling. The considerable reduction in the fourth and fifth ricks, which was most marked in the rear end of the car, is difficult to explain. In the forward end, the motion of the train caused the last rick to slide away from the end of the car, and thus somewhat improved the ventilation. It is possible, then, that in the rear end the tendency of the mass of spokes to surge backward and forward whenever the continuous passage of the car was interrupted, together with the fact that a hole existed in the bottom of the car due to the breaking of a floor plank, may have provided sufficient ventilation to account for the low percentage of mold in the fourth and fifth ricks.

It was noted that the stage in the development of the mold on the creosoted material was an early one, namely, a white, fluffy mycelium, which in most cases had not advanced to the spore-producing condition. This indicates a retarding effect due to the treatment. It is

also evident that the creosote, though unable entirely to control the mold, seemed to prevent the development of sap-stain. From the evidence it would also appear that heating the creosote to 150° or 155° F. does not increase its effectiveness to any marked degree, the difference in the percentage of moldy spokes in the two treatments being less than 1 per cent.

METHOD OF LOADING CAR NO. 2.

The second car, containing 1,032 salted, 1,013 borax-treated, 300 lime-treated red-oak, and the remainder untreated, white-oak escort spokes, was loaded on August 3 and 5.

FIG. 19.—"Ricking," or stacking, treated escort spokes in a box car (car No. 2).

Those spokes that had been salted were exceedingly moist, owing to the hygroscopic property of the salt. On many of these species of Penicillium were found. The limed spokes were dark in color and in a few cases seemed to be developing sap-stain. The borax-treated spokes were apparently quite free from fungi.

The method used for stacking the spokes in the second car differed somewhat from that in the first. The base of each rick was constructed in the same manner, though of four instead of six layers. Upon this base the spokes were carefully stacked, using two 1½-inch by ¼-inch crossers of elm between successive layers (fig. 19). Each rick held on an average 840 spokes. The doorways were closed in the same manner as in car No. 1. This consignment left the yard on August 6 and arrived at the same factory located in the North on August 20, a period of two weeks in transit. During this time the weather was hot and comparatively dry.

CONDITION OF SPOKES IN CAR NO. 2 UPON ARRIVAL AT DESTINATION.

On August 21 the spokes were unloaded and inspected by C. J. Humphrey and the writer. Table II gives the location of the different lots and their condition upon arrival.

TABLE II.—*Condition of the spokes in car No. 2 upon arrival at its destination.*

Location in car.	Material.	Antiseptic.	Condition.	Percentage molded (based on 840 spokes per rick).
Ricks in the end of the car containing treated spokes:				
First rick	White oak	Untreated	147 moldy; a few sap-stained	17.5
	do	A few untreated layers at top	1 moldy	.1
Second rick	Red oak	Remaining layers borax, 5 per cent.	67 moldy; many sap-stained.	7.9
	do	Top layers borax, 5 per cent.	7 moldy; many sap-stained	.8
Third rick	do	Middle layers lime	4 moldy; some sap-stained. Spokes very dark in color.	.4
	do	Bottom layer salt	34 moldy; some sap-stained	4.0
Fourth rick	do	Salt	300 moldy; many with Penicillium in all parts of rick, badly damaged.	35.7
Fifth rick	White oak	Untreated	330 moldy; much sap-stain	39.3
Sixth rick	do	do	292 moldy; much sap-stain	34.8
Ricks in the doorway and in the opposite end of the car:				
In doorway	do	do	No mold; no sap-stain	0
First rick	do	do	87 moldy; many sap-stained	10.4
Second rick	do	do	312 moldy; many sap-stained	37.1
Third to sixth ricks.	do	do	Not examined	

The proportion of infected spokes, based on the total number in the different lots in the end of the car containing these spokes, is:

Untreated	29 per cent moldy.
Salted	32.3 per cent moldy.
Borax (treated)	7.3 per cent moldy.
Lime (treated)	1.3 per cent moldy.

These figures can by no means be used as a basis for an exact comparison of the values of the three preservatives. The location of the ricks in the car introduces another and very important factor. To note whether the hygroscopic property of the salt had a tendency to affect the humidity in the end of the car in which the salted spokes were stacked, thus influencing, perhaps, the amount of molding in adjacent lots, it was decided to observe the unloading of the spokes in the opposite end of the car. After two ricks had been unloaded, however, it became evident that this was not the case, as conditions in that end were practically the same as in the first. From the data derived, at least from this lot, given in Table II, it would seem that salt when applied dry to green spokes is of little value in controlling either sap-stain or mold. Lime, though effective in preventing both mold and sap-stain, yet because of its darkening effect on the wood and its tendency to form calcium carbonate, which cases over the surface and is said to dull the knives used in subsequent processes of manufacture, is debarred from further consideration. Borax, however, with 7.3 per cent moldy spokes, seems to be somewhat effective against mold, but of less value in controlling sap-stain.

SUMMARY OF OBSERVATIONS.

Creosote dipping seemed to prevent sap-staining, but it had little effect upon mold. In no way did it detract from the sale value of the spokes.

The creosote bath at 80° to 90° F. was nearly as effective as at 150° to 155° F.

Mercuric chlorid, 1 per cent, seemed to be very effective in controlling both sap-stain and mold.

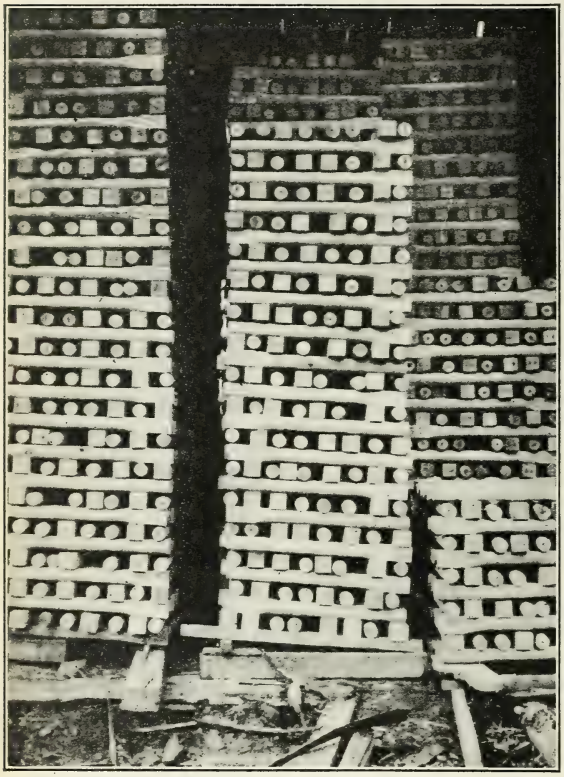


FIG. 20.—Green turned spokes cross piled in open or ventilated sheds. Green spokes are sometimes allowed to surface dry in this manner for one to two months preparatory to shipping in box cars.

Borax solution, 5 per cent, appeared to be somewhat effective in controlling mold, but of less value in regard to sap-stain.

The use of lime in the treatment of spokes was not satisfactory, on account of its darkening effect on the wood, the covering up of physical defects, and the probability of dulling the knives used in later processes of manufacture.

Salt sprinkled over the spokes was of no value in preventing either mold or sap-stain.

The ventilation of spokes in a box car is an important factor. Those spokes in the doorway, even if untreated, usually have but little tendency to mold or sap-stain.

Practically none of the spokes in either car were culled on account of defects due to fungi, although a few in the areaway between the doors were thrown out on account of slight checking.

No incipient decay was found in any of the material.

EXPERIMENTAL DIPPING OF RED-OAK BLOCKS AT THE LABORATORY OF FOREST PATHOLOGY, MADISON, WIS.

A comparison of the specific antiseptic values of the chemical substances employed in the spoke-dipping experiments can hardly be made, since these substances were not used in solutions of uniform strength. To determine, if possible, the comparative values of these and several other common antiseptics and preservatives in the control of mold and sap-stain fungi, several series of experiments were undertaken at the Madison laboratory. Where possible, solutions were made up to a calculated value of 1 per cent actual weight of anhydrous salt. The hygroscopic substances—sodium chlorid, calcium chlorid, and glycerin—were added in certain instances to determine whether or not they would increase the efficiency of the preservative by keeping the surface of the treated wood moist. A list of the substances used follows:

FIG. 21.—Storage of spokes in a warehouse. The truck spokes at the left have just been painted by girls with a resin-linseed oil mixture to prevent checking.

Alum (potassium).
Ammonium fluorid.
Bleaching powder.
Borax.
Copper sulphate.
Lead acetate.
Lead nitrate.
Magnesium silicofluorid.
Mercuric chlorid.
Mercuric chlorid and hydrochloric acid, 1 per cent.
Potassium chlorate.
Sodium fluorid.
Sodium bifluorid.
Zinc silicofluorid.
Creosote in kerosene.
Formalin.
Lysol.
Mykantin.
Orthonitrophenol.
Rongalite.

Red-oak blocks $\frac{3}{4}$ by $\frac{3}{4}$ by $1\frac{1}{2}$ inches long, sawed from the sapwood of summer-cut logs, were used in each case. Ten blocks constituted a group. The individual blocks of a group were immersed for approximately 10 seconds in one of the respective solutions, drained, and then sprayed on all six sides with a water suspension of the spores taken from the same cultures as those used in the steaming experiments.[24] The sprayed blocks of each group were then close piled and placed in the tile chamber mentioned on page 29. An in-

[24] See page 29 for the list of fungi.

terval of at least 1½ inches was maintained between adjacent groups. In the tile chamber the blocks were subjected to a temperature averaging 80° F. and a relative humidity varying from 85 to 100 per cent. At the end of three to four weeks all blocks were carefully examined. The following observations were made at that time:

None of the preservatives was entirely effective in controlling mold when used in concentrations of 1 per cent.

Blocks dipped in sodium carbonate, sodium bicarbonate, sodium fluorid, sodium bifluorid, ammonium fluorid, magnesium silicofluorid, zinc silicofluorid, and bleaching powder became badly molded.

Potassium (alum), potassium chlorate, and copper sulphate seemed to stimulate all or certain species of the fungi used. The last seemed to incite the growth of *Aspergillus niger* in particular.

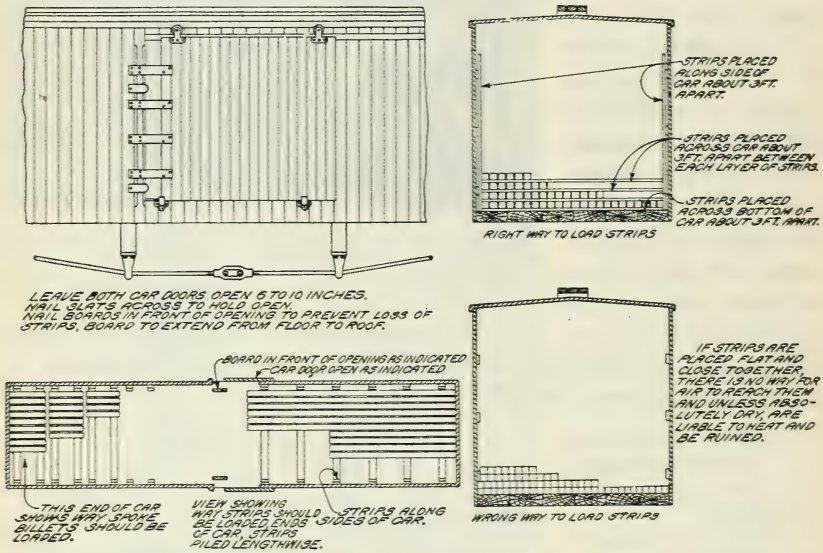

STRIPS PLACED ALONG SIDE OF CAR ABOUT 3FT. APART.
STRIPS PLACED ACROSS CAR ABOUT 3FT. APART BETWEEN EACH LAYER OF STRIPS.
STRIPS PLACED ACROSS BOTTOM OF CAR ABOUT 3FT. APART.
RIGHT WAY TO LOAD STRIPS
LEAVE BOTH CAR DOORS OPEN 6 TO 10 INCHES. NAIL SLATS ACROSS TO HOLD OPEN. NAIL BOARDS IN FRONT OF OPENING TO PREVENT LOSS OF STRIPS. BOARD TO EXTEND FROM FLOOR TO ROOF.
BOARD IN FRONT OF OPENING AS INDICATED
CAR DOOR OPEN AS INDICATED
IF STRIPS ARE PLACED FLAT AND CLOSE TOGETHER, THERE IS NO WAY FOR AIR TO REACH THEM AND UNLESS ABSOLUTELY DRY, ARE LIABLE TO HEAT AND BE RUINED.
THIS END OF CAR SHOWS WAY SPOKE BILLETS SHOULD BE LOADED.
VIEW SHOWING WAY STRIPS SHOULD BE LOADED, ENDS OF CAR, STRIPS PILED LENGTHWISE.
STRIPS ALONG SIDES OF CAR.
WRONG WAY TO LOAD STRIPS

FIG. 22.—Diagram illustrating the method of loading used by one of the large wheel factories and recommended by the wood-stock committee in connection with vehicle stock.

Borax was effective in controlling the sap-stain fungus (*Ceratostomella* sp.). Though it did not entirely prevent the growth of mold, the amount of mold that did develop was very slight in comparison with that on the blocks treated with the other preservative solutions. Under these circumstances it compared favorably with 1 per cent mercuric chlorid.

The addition of the hygroscopic substances—sodium chlorid, calcium chlorid, and glycerin—to the solutions of the preservatives apparently did not increase their efficiency.

Of the organic compounds and mixtures tested here, creosote in kerosene gave the best results, while mykantin stood second. The latter, however, stained the wood yellow, a property which would prohibit its use for many purposes.

STORAGE OF GREEN DIMENSION, SAWED, OR TURNED STOCK AT THE MILL.

If it becomes necessary to store dimension or turned green stock without giving it the protection referred to, cross piling or stripping in properly ventilated sheds is absolutely essential (figs. 20 and 21). All strips should be narrow and at least three-fourths of an inch, but preferably 1 inch, in thickness and should be thoroughly seasoned or given some antiseptic treatment.

HANDLING GREEN DIMENSION, SAWED, OR TURNED STOCK IN TRANSIT.

If it becomes necessary to ship green dimension, sawed, or turned stock and planks during the late spring and summer months, attention must be paid to the cleanliness and ventilation of such material while in transit.[25] Cattle, vegetable, or ventilated box cars which have been previously cleaned are to be preferred for small stock. In ventilated box cars the end doors should be cleated open. If only box cars of the ordinary type are available, the material should be piled according to methods similar to the one shown in figure 22. In the case of spokes and sawed billets, a cross-piled foundation, four to six courses high, is recommended in addition to the directions given (figs. 23 and 24).

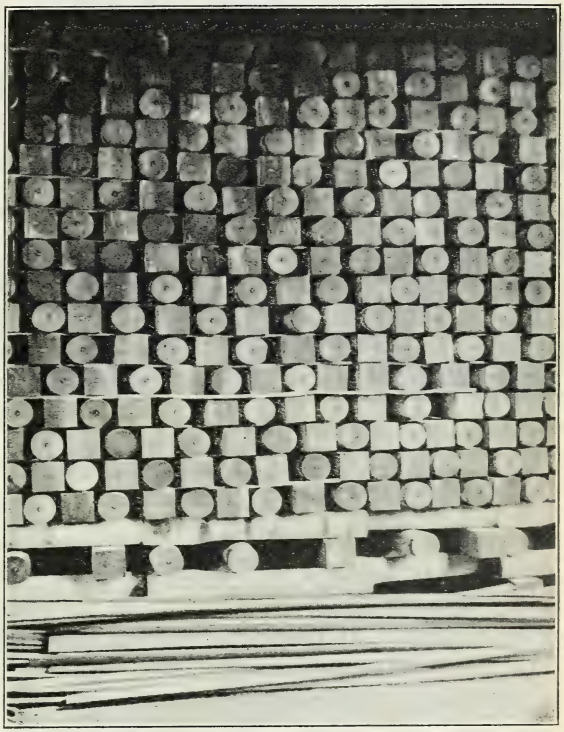


FIG. 23.—Artillery spokes "ricked" in a box car. Elm strips one-half inch by 1½ inches used between the courses.

When doors of box cars are loosely boarded up (fig. 25) or cleated open (figs. 9 and 22), it is recommended that they be spiked, that the bill of lading bear an indorsement to the effect that the doors were left open and cleated at the request of the shipper, and finally that

[25] The directions given under "Provisions for the proper ventilation of stock in transit," page 23, apply here.

a notice similar to that devised by one of the wheel companies and cited in Bulletin No. 30 of the wood-stock committee [26] be nailed to the car, reading as follows:

> TAKE NOTICE.—Do not Close Doors.—The lumber in this car is green and is carefully cross piled that there may be good circulation of air through the stock. The doors are left partly open and cleated by the shipper upon request of the consignee. If the doors are closed the stock will be liable to damage in transit.
>
> Should this car break down in transit, making it necessary to transfer the stock to another car, it should be stacked in the car in the same manner and doors left open in the same way.

The use of box cars is usually demanded by those in charge of bending mills where green rim stock is to be shipped. These cars expose the stock to less damage from checking. Unless attention is paid to stripping or some method of piling so as to insure ventilation, however, molding and sap-staining may result. One method used for the piling of rim strips in cars is shown in figure 26.

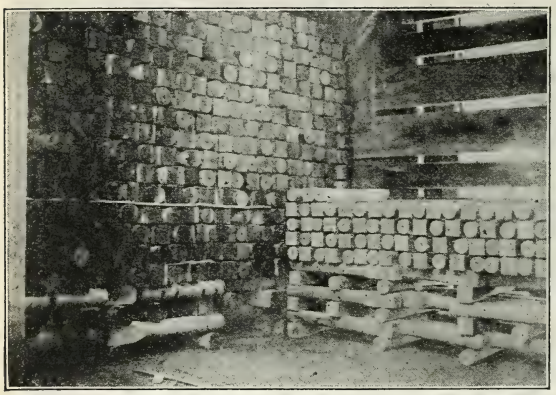


FIG. 24.—Artillery spokes "ricked" in a box car. A cross-piled base, strips, and open-boarded doorway are important details in the provision for proper ventilation of the stock while in transit.

SUMMARY.

It is evident that the prevention of sap-stain, mold, and incipient decay in green material, and in vehicle stock in particular, lies in a combination of remedial factors, the following being especially important: Care in the selection of raw stock in order to obtain, if possible, material free from fungous infections; expedition in the movement of raw stock from the felling of the logs to that time in the process of manufacture when the material becomes sufficiently dry to resist the attacks of fungi; provision at all times for ample ventilation of the stock that it may quickly become at least surface dried, thus making it difficult for the fungous spores to obtain from the exposed sapwood the moisture necessary for germination;

[26] National Implement and Vehicle Association and other Vehicle and Vehicle Parts Manufacturers. Information Division of the Wagon and Vehicle Committee and the Wheel Manufacturers' War Service Committee. Wood Stock Committee. Sap-stain and mold in transit. Nat. Implement and Vehicle Assoc., etc., Bul. 30, 5 p. 1918. A. B. Thielens, chairman. Typewritten.

the kiln drying of the stock wherever possible and whenever the cost will permit; and in special cases steam treatment or the use of antiseptic dips, followed by proper piling to insure ample ventilation.

It must be continually borne in mind that none of these is by itself a sovereign remedy. Preservative dips or steam treatment were not in themselves, under the emergency manufacturing conditions incident to the war, by any means sufficient to control molding of green stock when close piled in storage warehouses or while in transit in box cars.

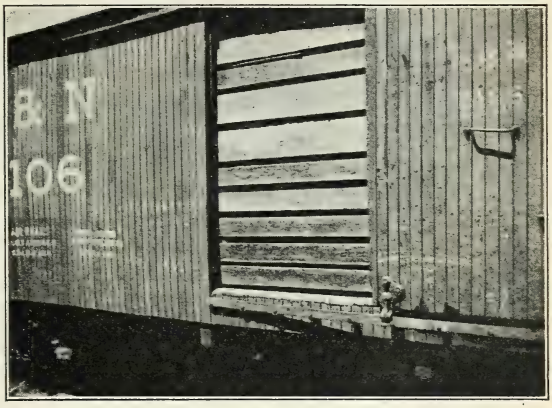


FIG. 25.—A box car loaded with spokes and ready for shipment. Spaces of 1½ inches are left between adjacent boards nailed across the doorways to allow for ventilation of the stock while in transit.

In connection with this investigation, it should also be borne in mind that we are dealing with three distinct groups of fungi, namely, the molds, staining organisms, and true wood-destroying organisms, the antiseptics being more efficient against the last two groups than the first. As far as is known, neither molds nor staining fungi cause any appreciable diminution in the strength of timber and hence are unimportant in vehicle manufacture from the standpoint of strength and probably durability. The staining fungi can be controlled to a certain extent by the intelligent use of antiseptics and possibly by steaming, and it seems reasonable, in the light of experience, to suppose that the development of wood-destroying fungi can also be prevented.

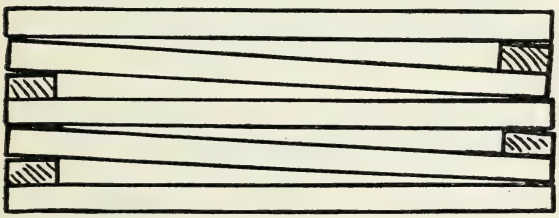


FIG. 26.—Zigzag method of piling rim strips in box cars.

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